FISCAL YEAR 1998

ARMY SCIENCE AND TECHNOLOGY MASTER PLAN

VOLUME I

DEPARTMENT OF THE ARMY
WASHINGTON, D.C. 20310

The *Army Science and Technology Master Plan* describes the technology investments that will prepare America's Army for the future. The plan focuses on developing affordable options to achieve the capabilities envisioned in Army Vision 2010, ensuring the timely development and transition of technology into the full-spectrum capabilities needed to support the soldier in the 21st century.

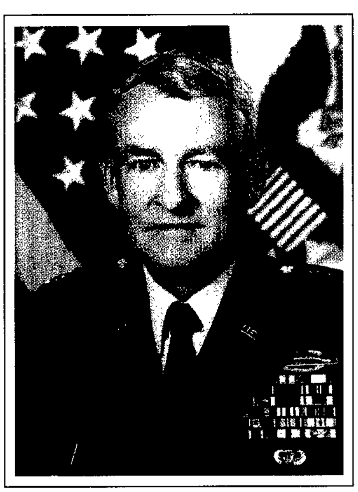
Our modernization plan balances the needs for current and long-term readiness. We will continue to focus on maintaining overmatching combat power and achieving Information Dominance in the near-term. In the long-term, we are developing the systems that will allow the Army to achieve Full Spectrum Dominance, an unprecedented warfighting ability to overwhelm any potential threat in any environment. In particular, our current investment strategy goals focus our efforts on developing the leap-ahead technologies required for Army After Next, the Army's future combat force that we will field in the 21st century.

In addition to being future oriented, the *Army's Science and Technology Master Plan* is also concerned about the force here and now, becoming as efficient and effective as possible. We have achieved considerable success in acquisition reform continuously evaluating the way we do business, ensuring our soldiers always have access to affordable and capable leading edge technology.

The *Army Science and Technology Master Plan* provides the focus and direction we need to maintain our decisive global military advantage, ensuring our soldiers are well equipped, trained, and ready for victory.

Dennis J. Reimer
General, United States Army
Chief of Staff

Louis Caldera
Secretary of the Army



DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY
RESEARCH DEVELOPMENT AND ACQUISITION
103 ARMY PENTAGON
WASHINGTON DC 20310-0103

REPLY TO
ATTENTION OF

19 MAR 1998

This annual edition of the *Army Science and Technology Master Plan* serves as "top down" guidance from Headquarters Department of the Army to all Army Science and Technology organizations and provides a vital link between the technology planning by the Department of Defense and the master plans of individual Army major commands, major subordinate commands, and laboratories.

The Army Science and Technology (S&T) program is an essential corporate investment in the Army of the future. A strong, focused, and stable S&T program is essential to ensure the timely development and transition of technologies into weapon systems and system upgrades and to explore alternative concepts to provide future warfighting capabilities for Force XXI, Army Vision 2010, and Army After Next.

The *Army Science and Technology Master Plan* is the Army's key S&T planning document providing a comprehensive, funding constrained picture of ongoing S&T efforts and roadmaps for transition to achieve the required capabilities of the future. We are committed to provide timely demonstrations of affordable technology/weapon system concepts to maintain and enhance our soldiers' decisive edge on the battlefield. We have a world-class network of Army-focused government and private S&T capabilities to maintain a smart buyer capability. And, we encourage reduced cost through our acquisition reform program, especially the early retirement of risk in materiel development programs.

We remain fully committed to shaping the future through sustained research and development to allow us to field a full-spectrum dominant land warfare force for the 21st Century while remaining focused on information dominance and maintaining combat overmatch. Central to our effort is the soldier – America's sons and daughters in uniform.

A. Fenner Milton
Deputy Assistant Secretary
for Research and Technology

Kenneth J. Oscar
Acting Assistant Secretary of the Army
(Research, Development and Acquisition)

Printed on Recycled Paper

Fiscal Year 1998

ARMY SCIENCE AND TECHNOLOGY MASTER PLAN

VOLUME I

JANUARY 1998

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FOREWORD

The DoD Science and Technology program is divided into three areas, each designed to bring technology to a different stage of maturity. The Basic Research (6.1) program exploits and identifies technological opportunities and provides an important interface with university and industry research. The Applied Research (6.2) program matures technology opportunities and evaluates technical feasibility for increased warfighting capability. The nonsystem-specific Advanced Technology Development (6.3) program demonstrates technologies to speed the transition of matured technology into the system-specific Demonstration/Validation (6.4) program or directly into Engineering and Manufacturing Development (6.5).

The *Army Science and Technology Master Plan* (ASTMP) is the Army's strategic plan for the science and technology program; it consists of two volumes. Volume I has these seven chapters:

- I—Strategy and Overview
- II—Training and Doctrine Command's Role in Science and Technology
- III—Technology Transition
- IV—Technology Development
- V—Basic Research
- VI—Infrastructure
- VII—Technology Transfer

Volume II contains annexes that, when combined with the budget, the program objective memorandum, and the Department of the Army Research, Development and Acquisition Plan, constitute the action plan for achieving the Volume I program.

Volume II contains the following annexes:

- Annex A—Science and Technology Objectives (STOs)
- Annex B—Advanced Technology Demonstrations (ATDs)
- Annex C—Interaction with TRADOC
- Annex D—Space and Missile Defense Technologies
- Annex E—Global Technology Capabilities and Trends
- Annex F—U.S. Special Operations Command Technology Overview
- Annex G—The Revolution in Military Logistics

The ASTMP is revised annually. Reader comments and suggested improvements are welcome. Please forward comments to:

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CHAPTER I

STRATEGY AND OVERVIEW

CONTENTS

CHAPTER I

STRATEGY AND OVERVIEW

History has given us the choice; science has given us the chance; love of country gives us the duty—to reach out to the future and pull it toward us.

William S. Cohen
Secretary of Defense

The *Army Science and Technology Master Plan* (ASTMP), annually revised and approved by the Secretary of the Army and the Army's Chief of Staff, provides Department of the Army guidance to all Army Science and Technology (S&T) organizations. As such, it is the strategic link between Department of Defense technology planning and the plans of Army major commands, major subordinate commands, and laboratories. This plan for the Army's S&T program is based on the Army leadership's vision of the future Army and available resources.

ARMY VISION

Army Vision 2010

The Army's vision is continuously evolving and results from the combined input of two critical planning activities—*Army Vision 2010* and *Army After Next* (AAN). *Army Vision 2010* is the blueprint for the Army's contributions to the operational concepts identified in *Joint Vision 2010*.

These activities identify the patterns of operations needed for the Army to fulfill its role in achieving full spectrum dominance as part of joint operations (Figure I–1). These patterns are (1) protect the force, (2) gain information dominance, (3) decisive operations, (4) shape the battlespace, (5) project the force, and (6) sustain the force. These patterns of operation align precisely with the *Joint Vision 2010* operational concepts of information dominance, dominant maneuver, precision engagement, focused logistics, and full dimensional protection.

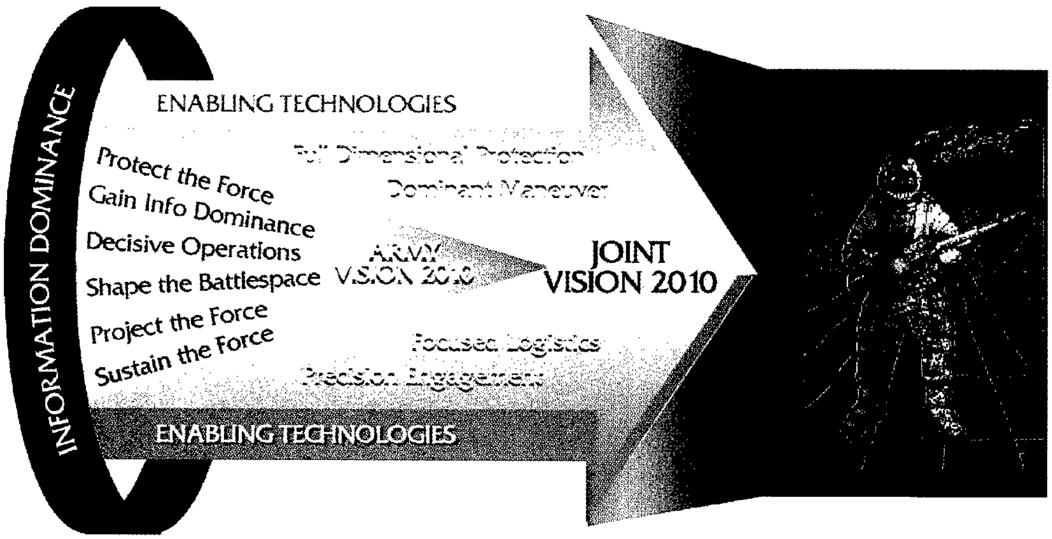


Figure I–1. *Army Vision 2010/Joint Vision 2010*

Army After Next

The Army's long-term vision is evolving through an AAN process being managed by Training and Doctrine Command (TRADOC) headquarters. The AAN office, under the Deputy Chief of Staff for Doctrine, is conducting broad studies of future warfare for the period around the year 2020 for the purpose of framing the issues vital to the development of the Army. The vision generated from these studies will be integrated into TRADOC combat development programs. Throughout this process the S&T community is serving a vital support role to TRADOC. To better appreciate the role of the S&T community in the emerging AAN vision, it is important to understand the four major azimuths the AAN study is exploring and the process for integrating these study results into the evolving AAN vision.

The first azimuth under investigation involves the identification of probable geopolitical realities for the period around 2020. The purpose of this study is to establish likely threats and missions and to link these to the Army's future warfighting strategies and systems to ensure that the Army will be able to fulfill its future National Command Authorities (NCA) responsibilities. The second is a study of the future military art necessary to ensure that the Army has unquestionable overmatch capability against the full spectrum of potential threats. The third azimuth is the evaluation of evolving technologies and systems concepts along with the planning of the S&T investments necessary to support the evolving military art and ensure unquestionable overmatch capabilities for the future Army. The fourth is the exploration of approaches necessary for our forces to operate effectively at the limit of human cognitive capability.

As illustrated in Figure I–2, the AAN process incorporates input and activities from multiple sources on an annual basis. This process begins with notional AAN operational concepts developed by TRADOC. These notional concepts are initially evaluated in tactical and strategic wargames. Attractive notional concepts of operations emerging from the wargames are subsequently analyzed by an Integrated Idea Team (IIT) composed of leading

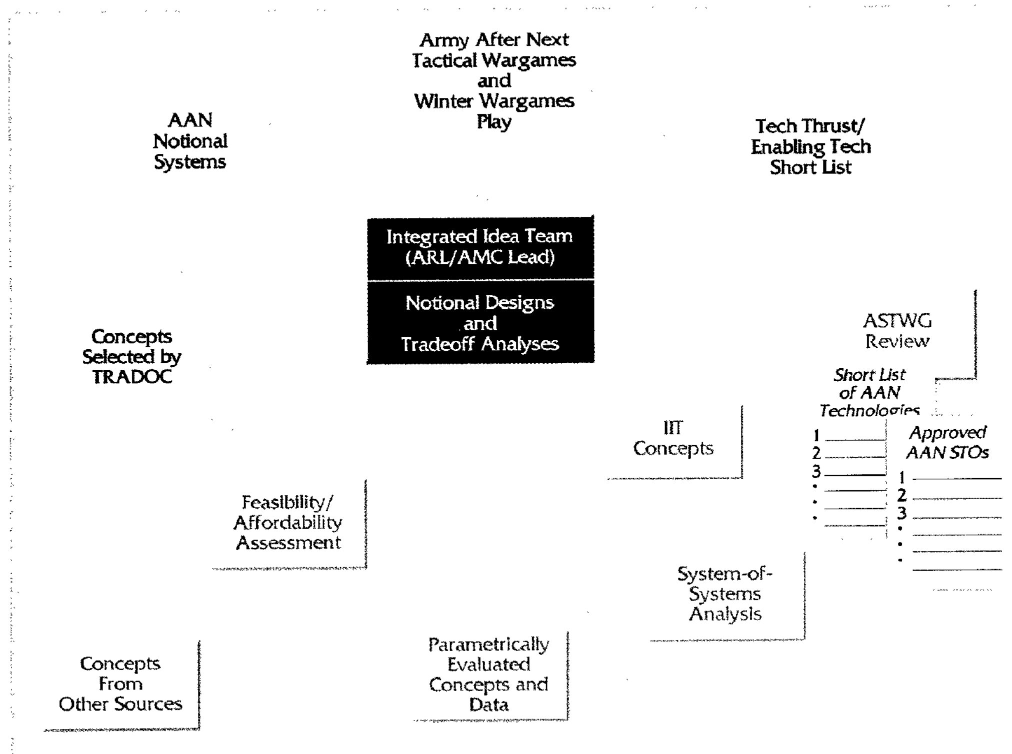


Figure I–2. Science and Technology Support to *Army After Next* Concept Development

Army scientists and engineers drawn primarily from Army Materiel Command (AMC) organizations, industry, and the Army Research Institute for Behavioral and Social Sciences (ARI), Medical Research and Materiel Command (MRMC), U.S. Army Corps of Engineers (USACE), the Space and Missile Defense Command (SMDC), and other organizations for the purpose of defining notional system concepts. The IIT develops point designs for these notional systems based upon scientific and engineering judgments. The TRADOC Analysis Center (TRAC) and RAND parametrically evaluate these point designs in a system-of-systems approach for the purpose of assessing their military utility and providing guidance on how to optimize the force structure that employs them. Further, an independent feasibility and affordability team, using expertise from industry, military laboratories, and academia, evaluates the emerging system concepts for technical feasibility and affordability. The subsequent concepts refined by this process are sent to TRADOC for evaluation. Those system concepts accepted by TRADOC are played in subsequent wargames. The IIT and the feasibility and affordability teams help TRADOC identify technologies that need advancement.

Through the processes described above, a strong S&T investment strategy in support of AAN has begun to evolve. Given the timeframe of AAN (2020), the 6.1 and 6.2 accounts (basic and applied research) are the most relevant. Although practically all the ongoing 6.1 and 6.2 investment has been found to be relevant to a broad definition of AAN, closely coordinated efforts with TRADOC are under way to realign the 6.1 and 6.2 accounts to obtain increased focus on those technologies where progress is most needed to enable AAN

concepts of operations. Specifically, the goal of this effort is to increase the 6.1 AAN-oriented Strategic Research Objectives (SROs) investment from 15 to 30 percent and to increase that portion of the 6.2 accounts focused specifically on AAN priorities. New SROs are being developed to synergistically focus various multidisciplinary research efforts on major research themes relevant to AAN (see Chapter V).

As part of this effort, a new 6.2 AAN Science and Technology Objective (STO) enhancement program has been budgeted for FY99 to encourage new 6.2 STOs to focus on AAN issues (Figure I–3). To achieve this objective, an AAN short list of high-priority, enabling technology thrusts resulting from the wargames process has been approved by TRADOC, distributed throughout the S&T community, and will be the basis for selection of enhanced AAN STOs through the Army Science and Technology Working Group (ASTWG) process.

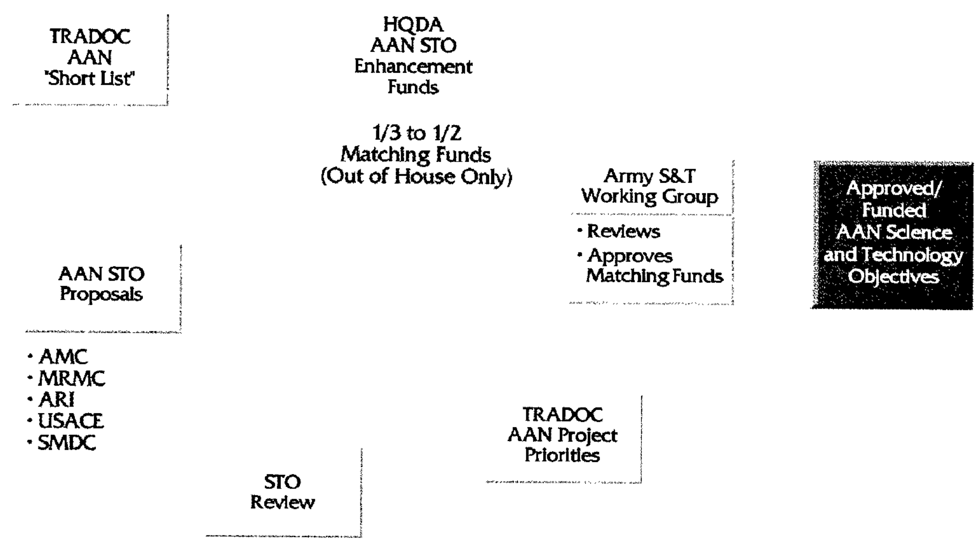


Figure I–3. ***Army After Next*** **Science and Technology Objectives**

Several independent assessments of S&T opportunities in support of AAN have also been initiated. Through the National Research Council's Board on Army Science and Technology (BAST), an Army Science and Technology study on logistics demand has been initiated. The BAST is conducting a study to identify those 6.1 and 6.2 efforts that would enable system concepts that greatly reduce logistics demand in the timeframe of AAN. From this evaluation, the BAST is to propose an S&T investment plan and roadmap.

In addition, an Army Science Board (ASB) summer study has been chartered to assess S&T opportunities in support of AAN. The ASB is to provide comments on enabling technologies that could support a broad view of Army capabilities needed in 2020, and review and comment on the process described in Figure I–3.

ARMY SCIENCE AND TECHNOLOGY STRATEGY

Science and Technology Vision

Supporting current and future Army visions, the Army S&T investment ensures the following results:

- Timely demonstrations of affordable technology/weapon system concepts that enable
  - Decisive overmatch with minimum casualties
  - Force projection with full spectrum capability
  - Requirements definition/prioritization through experimentation.
- S&T that reduces cost through
  - Early retirement of risk in materiel development programs
  - Support for acquisition reform.
- World-class network of Army-focused government and private S&T that
  - Maintains land warfare superiority
  - Leverages commercial technology
  - Maintains smart buyer capability
  - Enables AAN.

Figure I–4 illustrates how the S&T investment strategy supports Army modernization objectives into the next century.

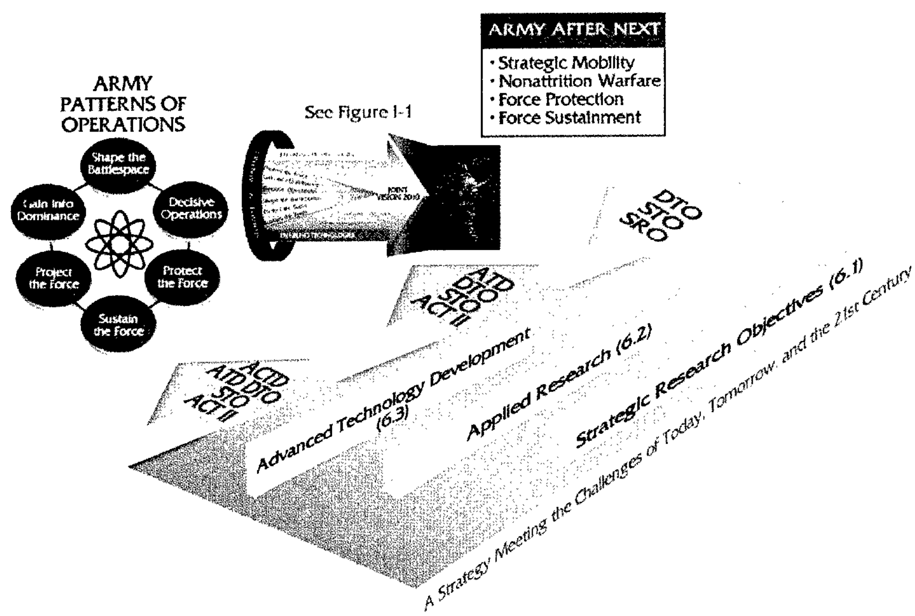


Figure I–4. Science and Technology Investment Strategy

Strategic Objectives

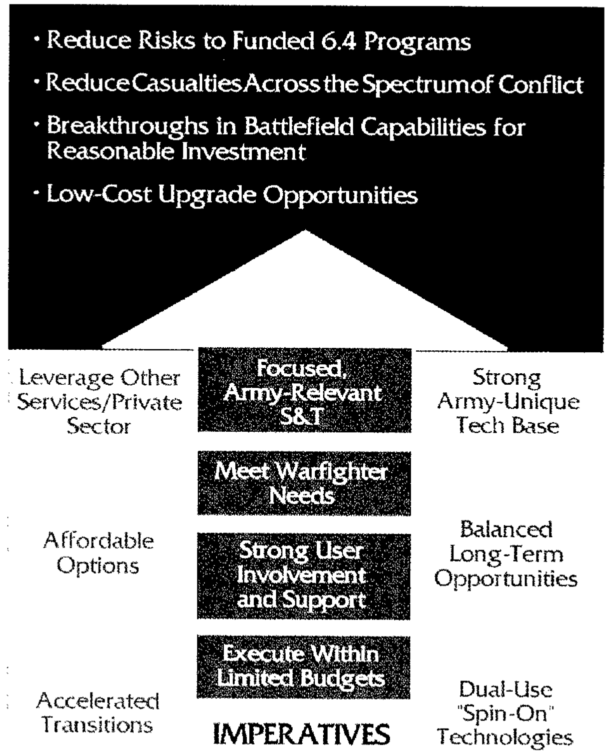


Figure I–5. Strategic Investment Objectives

To support the S&T vision, the Army has several strategic investment objectives (Figure I–5):

- Comply with and support the *Defense S&T Strategy* and the Army vision, *Army Vision 2010*, and emerging concepts for the AAN.
- Conduct world-class relevant research.
- Strengthen the requirements process through
  - System-of-systems demonstrations.
  - Advanced Technology Demonstrations (ATDs) and Advanced Concept Technology Demonstrations (ACTDs).
  - S&T synchronized with TRADOC Advanced Warfighting Experiments (AWEs).
- Support the Advanced Concepts and Technology II (ACT II) program.
- Provide affordable options with a focus on system upgrades.
- Improve technology transition, while coupling S&T to development programs.
- Improve technology transfer and "spin on" by forming partnerships with academia and industry.
- Stabilize S&T priorities and funding.
- Improve program execution and oversight.
- Attract, develop, and retain quality scientists and engineers.
- Downsize the infrastructure.

Planning Process and Oversight

The Army's Science and Technology program, as reflected in this year's ASTMP, identifies the S&T investments needed to achieve this vision and supporting objectives. It provides an action plan for mobilizing government, industry, and academic resources. The ASTMP position in the overall Department of Defense strategic planning hierarchy is shown in Figure I–6. Army leadership oversight of the Army S&T program is provided by the Army Science and Technology Advisory Group (ASTAG), which is co-chaired by the Army Acquisition Executive and the Vice Chief of Staff, Army (Figure I–7). The ASTWG is

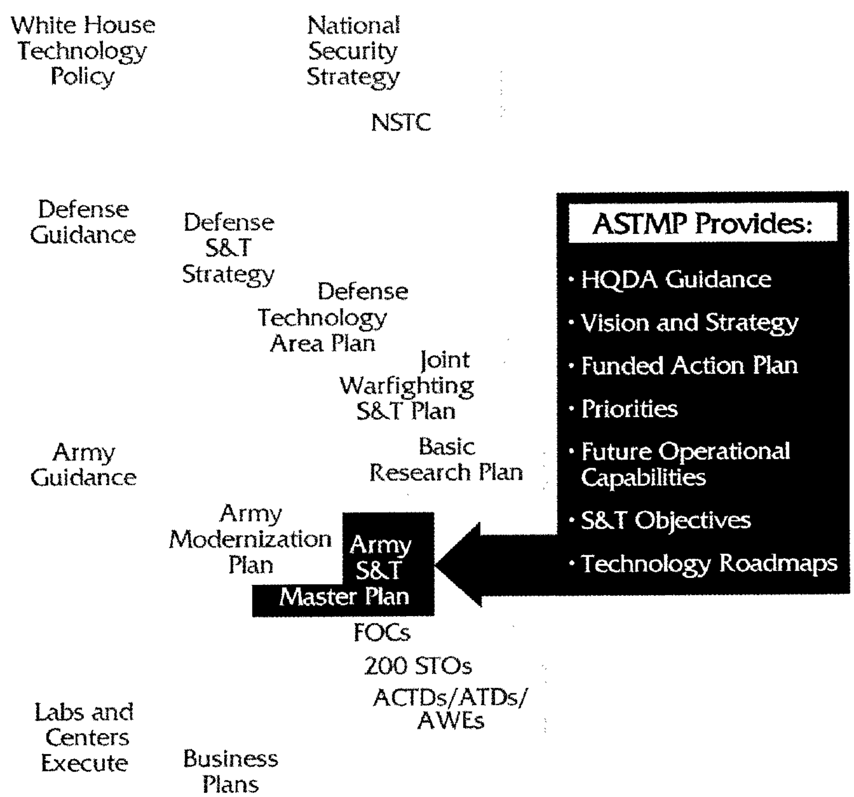


Figure I–6. Hierarchy of Plans

co-chaired by the Army Science and Technology Executive (the Deputy Assistant Secretary for Research and Technology) and the Assistant Deputy Chief of Staff for Operations and Plans (Force Development). The ASTWG provides general-officer-level resolution of pressing S&T issues prior to meetings of the ASTAG, recommends to the ASTAG revisions to the Army's S&T vision, strategy, principles, and priorities, and reviews and approves ATDs, STOs, and Manufacturing Technology Objectives (MTOs). The overall planning process for the Army S&T program is shown in Figure I–8. The preparation and approval of the ASTMP is shown in the upper part of the diagram, and its progress through the overall Army planning and budgeting process is shown in the lower part.

Science and Technology Objectives

To provide guidance to the S&T community, the Army has established a set of 200 Science and Technology Objectives. A STO states a specific, measurable, major technological advancement to be achieved by a specific fiscal year (Figure I–9). It must be consistent with the funding available in the current year budget, the Future-Years Defense Plan (FYDP), and the Program Objective Memorandum (POM). Not every worthwhile funded 6.2 and 6.3 technology program will be cited as a STO in part because the Army must

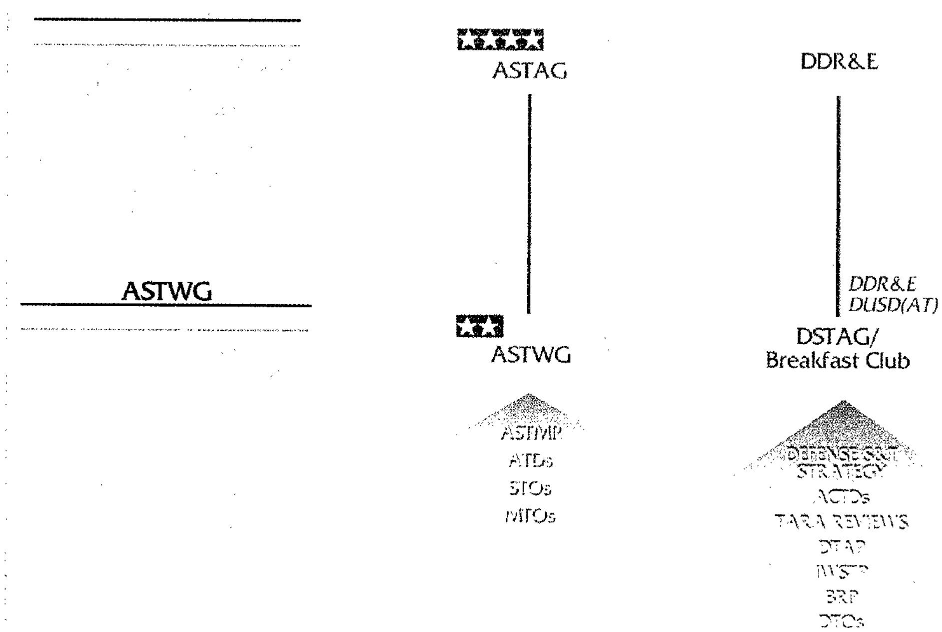


Figure I–7. Army/Office of the Secretary of Defense Science and Technology Oversight

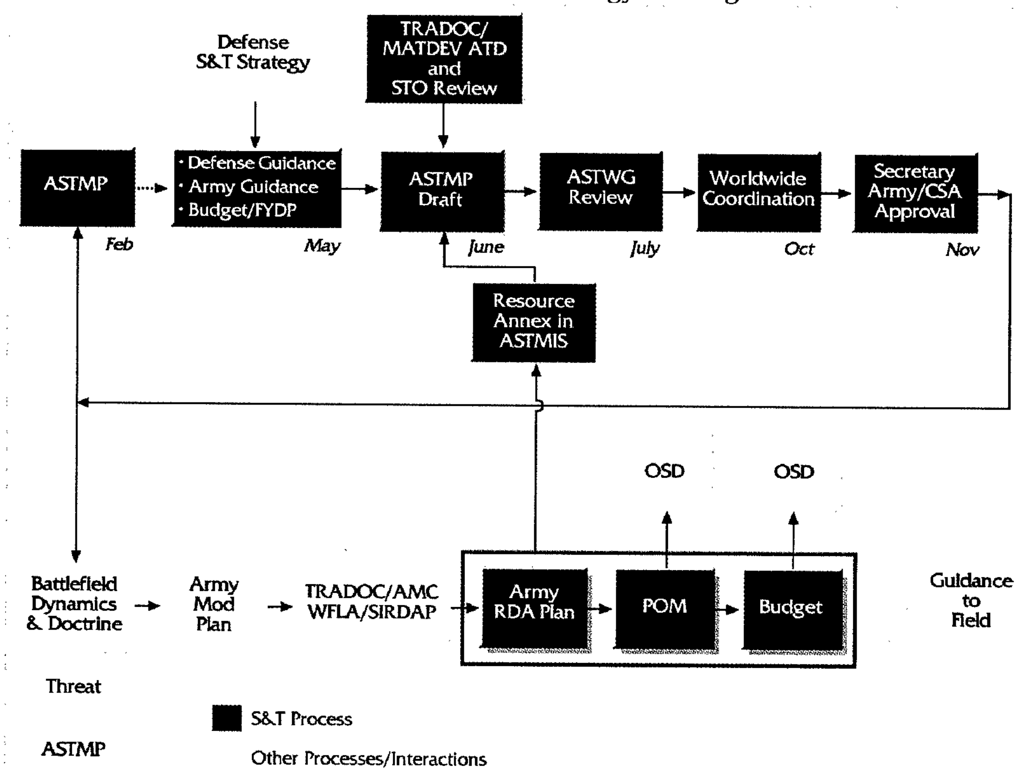


Figure I–8. Army Science and Technology Planning Process

reserve some program flexibility for the laboratory or center director to seize opportunities within his or her organization, based upon the organization's local talents and resources.

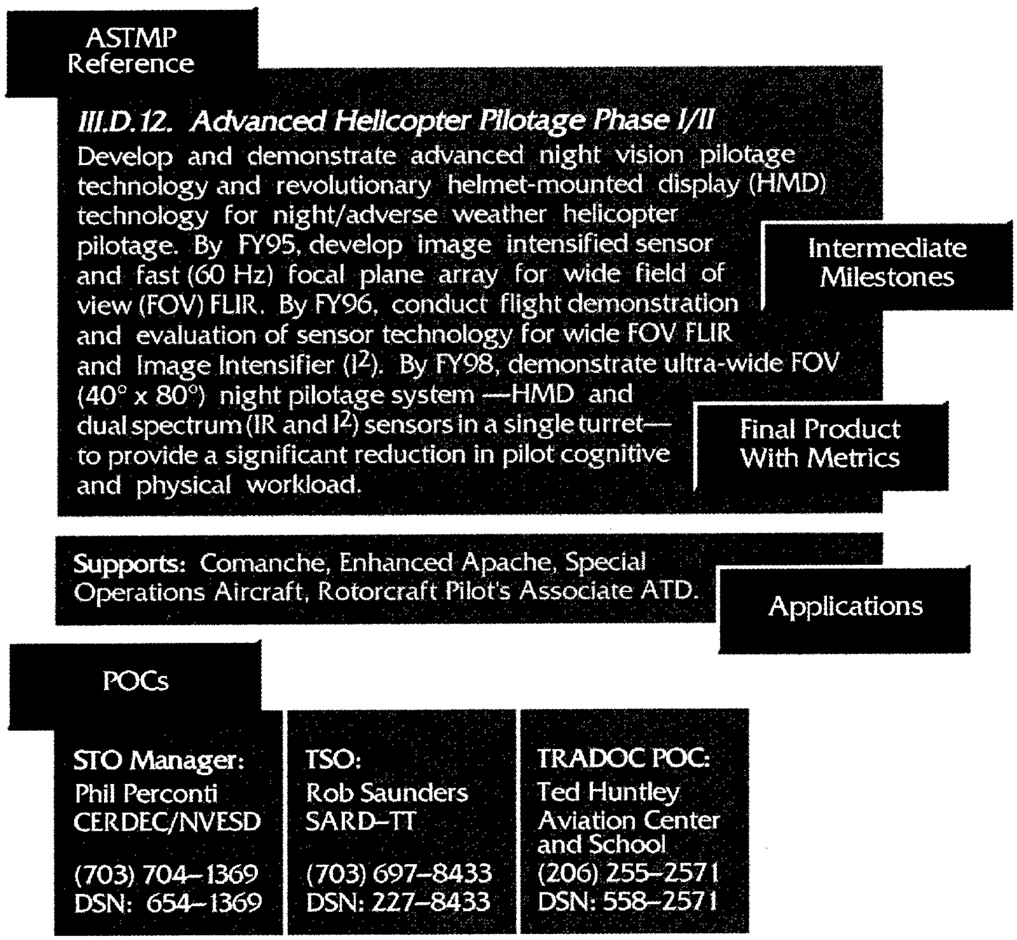


Figure I–9. Anatomy of an STO

The Army uses the STOs to focus and stabilize the 6.2 and 6.3 program, practice management by objectives, and provide feedback to our scientists and engineers regarding their productivity and customer satisfaction. STOs are reviewed annually at a joint materiel developer/TRADOC meeting and then reviewed and approved by the ASTWG (Figure I–10). STOs, revised as necessary to maintain currency and consistency with economic factors, ensure TRADOC input to the planning process, and provide Army leadership guidance to S&T performing organizations. All Army Planning, Programming, Budgeting, and Execution System (PPBES) submissions, including budget estimates and execution plans and Defense Technology Objectives (DTOs), should comply with the STO guidance. Descriptions of current STOs are given in Volume II, Annex A, of this document and in the Army Science and Technology Management Information System (ASTMIS).

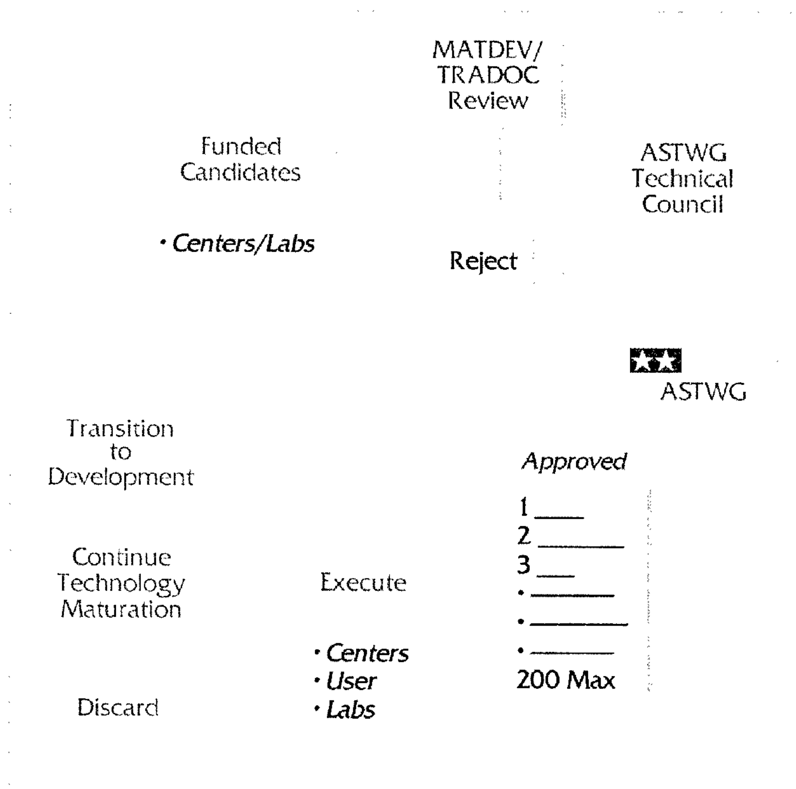


Figure I–10. Science and Technology Objective Process

Resourcing the Strategy

Figure I–11 shows how the 6.1, 6.2, and 6.3 funding categories relate to the overall acquisition process. Figure I–12 shows Army S&T recent and future funding levels.

The 6.1 research includes all efforts of scientific study and experimentation with a high potential to significantly improve land warfighting capabilities. In this basic research category (6.1), the Army maintains a strong peer-reviewed scientific base providing the foundation for technological improvements to warfighting capability through university and in-house research. In addition to conducting in-house research, Army scientists monitor developments in academia and industry and evaluate the many proposals received for 6.1 funds (Figure I–13). (See also Chapters V and VII.)

Applied Research (6.2) includes all efforts directed toward the solution of specific military problems, short of major demonstrations and development projects. This applied research category includes the development of components, models, and new concepts through in-house and industry efforts. Individual research programs often enable a variety of new systems and support a number of identified needs. Since research programs may readily contribute to needs in several mission areas, the Army performs horizontal integration, or "cross-mission-area analyses," to understand 6.2 funding priorities.

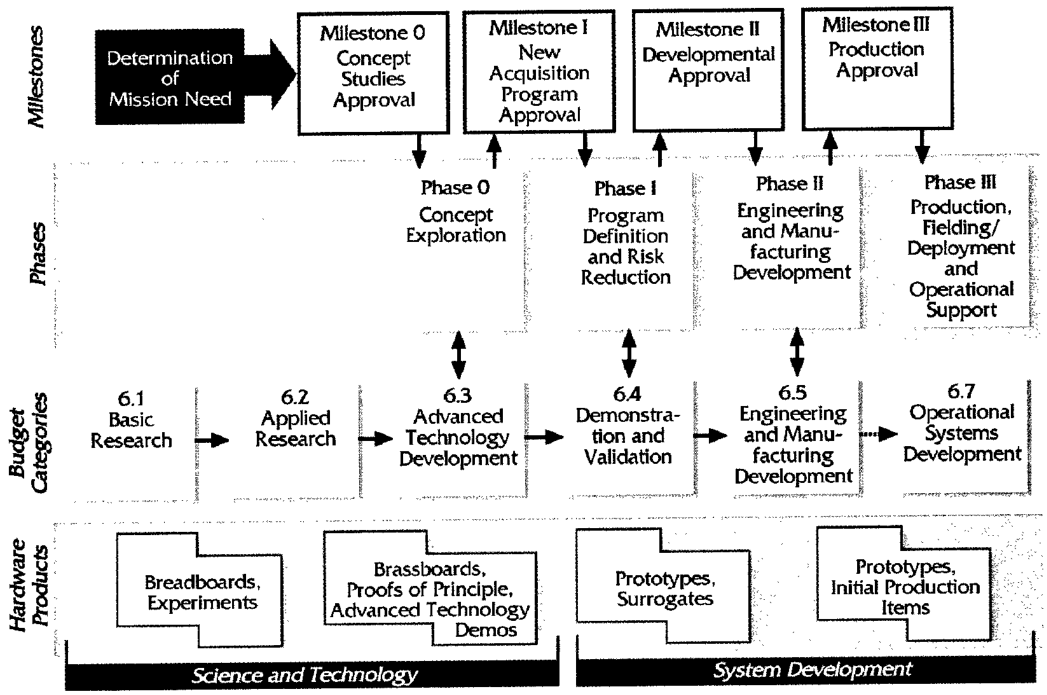


Figure I–11. Science and Technology Related to the Acquisition Process

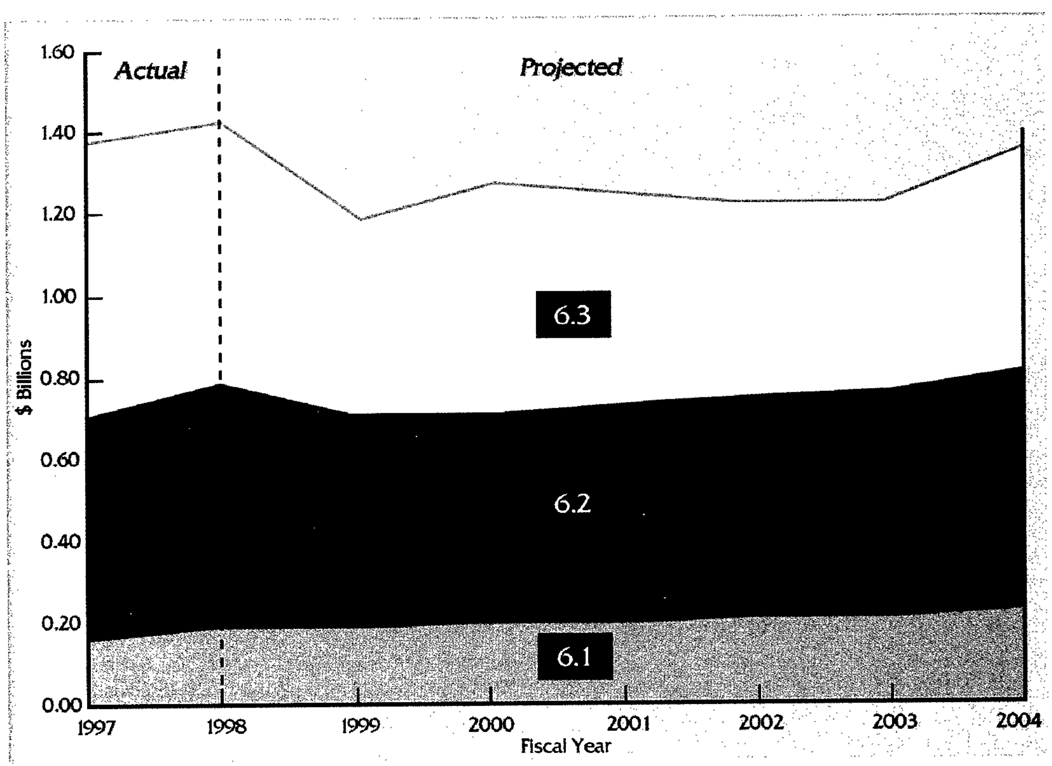


Figure I–12. Science and Technology Program Funding by Budget Category

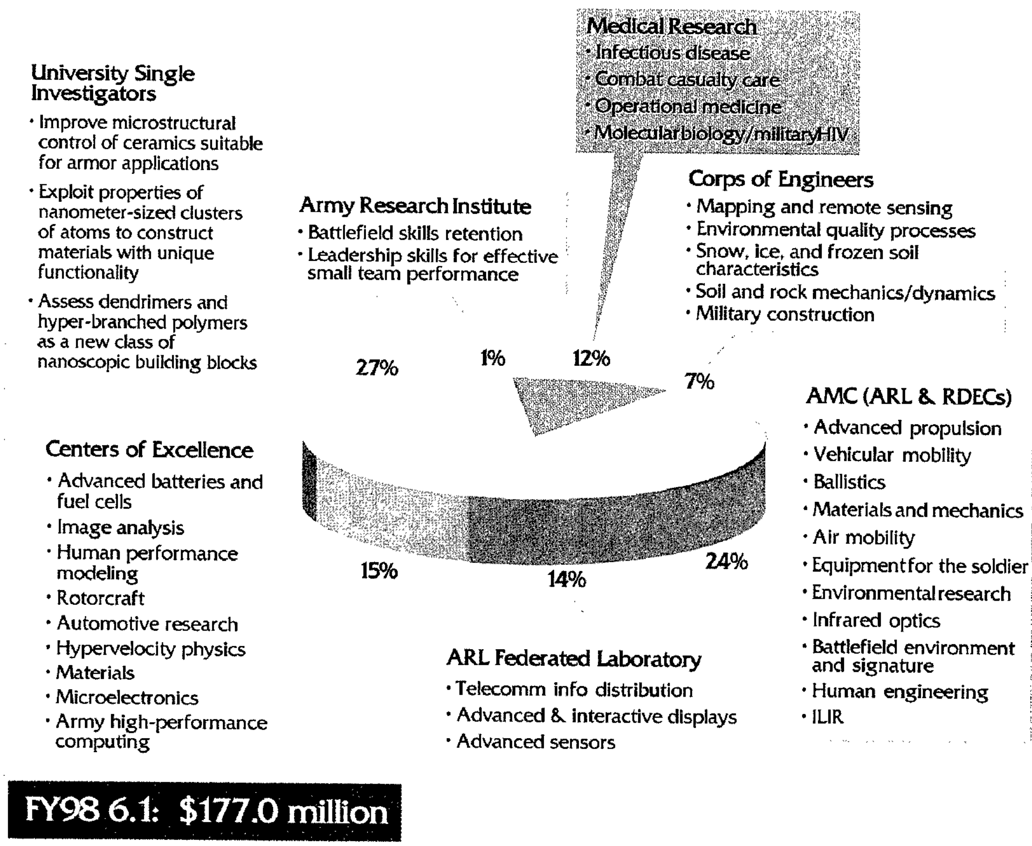


Figure I–13. Army Basic Research

Advanced Technology Development (6.3) includes all efforts directed toward projects that have moved into demonstration of hardware or software for operational feasibility. In the 6.3 category, experimental systems or subsystems are demonstrated to prove the technical feasibility and military utility of the approach selected. Advanced technology development (6.3) provides the path for the rapid insertion of new technologies into Army systems, be they new systems or product improvements. The Army establishes priorities for demonstrations that are needed prior to the development of the most critically needed systems and product improvements. The criteria for selection of 6.3 programs are:

- Reduce risks to funded 6.4 programs.
- Reduce casualties across the spectrum of conflict, including asymmetric threats.
- Breakthroughs in battlefield capabilities for reasonable investment.
- Low-cost upgrade opportunities.

Figure I–14 shows the Army S&T FY98 6.3 appropriated program and includes ATDs, ACTDs, and TDs, many of which form system-of-systems demonstrations.

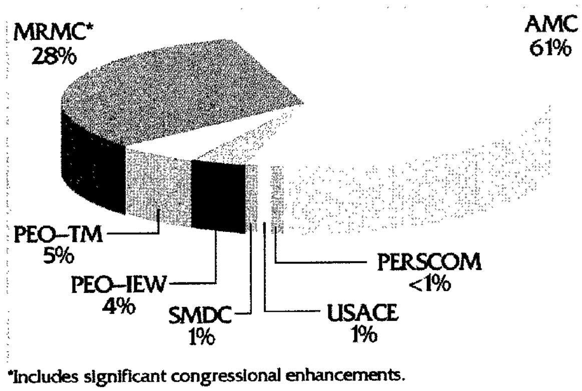


Figure I–14. FY98 6.3 Appropriated Program Total = $657.5 Million

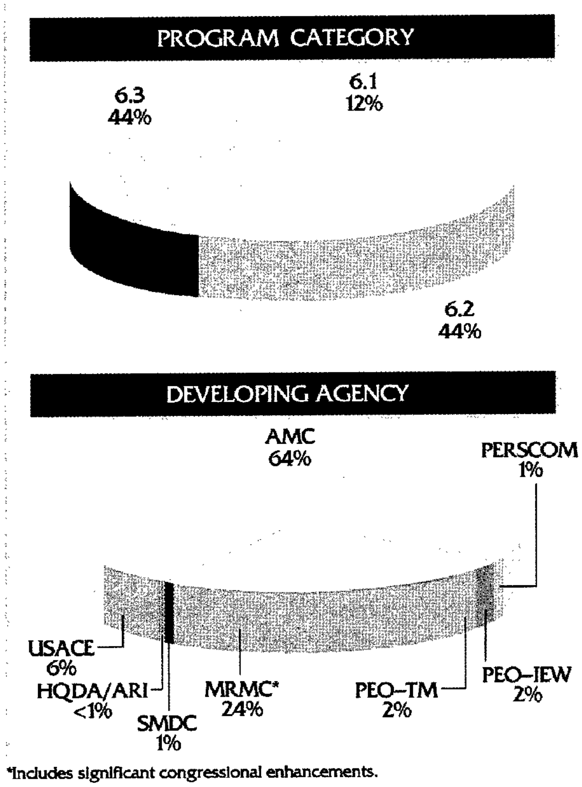


Figure I–15. FY98 Science and Technology (6.1, 6.2, 6.3) Appropriated Program

The Army policy is to maintain stable funding for Army S&T. This stability principle of our investment strategy is consistent with the long-term nature of basic and applied research. Stability of focus and funding permits the Army's scientists and engineers to conduct meaningful long-range planning to ensure that the technologies required to address future warfighting needs and obtain AAN goals will be available when needed. Figure I–15 shows the FY98 S&T appropriation by program and developing agency.

Technology Transfer

Technology transfer covers all interactions with external organizations, whether transferring technology into or out of the S&T program. It should be distinguished from technology transition, which deals with the maturing of technology within the S&T program and transitioning it to development (6.4 or 6.5 programs). The Army continuously monitors new commercial developments looking for military applications. This spin-on of technology is of growing importance to the Army S&T program—not only from the domestic R&D programs but also from development overseas (see Volume II, Annex E). Conversely, where military R&D is in the lead (e.g., rotorcraft, night vision, propulsion), technology transfer to commercial uses is actively pursued.

Since Army S&T makes up less than 1 percent of the total national investment in R&D, the Army leverages R&D from industry, universities, other government organizations, and foreign sources. Industry independent research and development (IR&D) activities are planned, performed, and funded by companies in order to maintain or improve their technical competence or to develop new or improved products. Contractors may be reimbursed

up to 100 percent of their IR&D expenditures if they are part of the overhead cost to the government. Industry IR&D efforts amount to more than $2 billion annually.

To effectively exploit the overall industrial base, the Army is also an aggressive partner in the development of dual-use technologies. By investing in dual-use technology, the Army can exploit the efficiencies generated through the use of common production lines for commercial and military products, reap the reduced costs resulting from larger scale production runs, and leverage industry's willingness to invest in commercially viable technologies. The Army targets dual-use projects in areas such as automotive, aviation, medical, construction engineering, environmental, pollution abatement/control, telecommunications, sensors, and individual soldier technology. Beginning in FY99, the Army will manage the Dual-Use Applications Program (DUAP) S&T initiative devolved by Congress from DoD. This initiative provides incentive funding to support dual-use technology projects. These funds are matched by lab/center funds, and the total of these two is matched by the industry partner(s). DUAP projects therefore involve a mix of Army (25 percent), DUAP (25 percent), and industry (50 percent) funding, using cooperative agreements or other transactions for their execution. The cost sharing by industry demonstrates its commitment to exploit the resulting technology for military as well as commercial applications.

Technology transfer is also made easier by the growing DoD adoption of commercial products, practices, and processes, and by the DoD Project Reliance.

Cooperative Research and Development Agreements

It is Army policy to actively market technology that can benefit the public and private sectors and to respond quickly to requests for technical assistance. The mechanisms for accomplishing this are Cooperative R&D Agreements (CRDAs), the Construction Productivity Advancement Research (CPAR) program, Patent License Agreements (PLAs), and technical outreach programs. The cumulative Army totals from FY89 to FY98 are 1,083 CRDAs, including CPAR agreements, and 87 PLAs. The Army has more cooperative agreements than all the rest of DoD combined (see Chapter VII).

National Automotive Center

Recognizing the many dual-use benefits to be exchanged among industry, academia, and government, the Army established the National Automotive Center (NAC) in 1993 (Figure I–16). The NAC is located at the U.S. Army Tank–Automotive Research, Development and Engineering Center, Warren, Michigan, and serves to facilitate the transfer of dual-use automotive technologies from the commercial sector to the military and vice versa.

National Rotorcraft Technology Center

The National Rotorcraft Technology Center (NRTC), established in 1996, is a catalyst for facilitating collaborative rotorcraft research and development among the DoD (Army and Navy), NASA, the Federal Aviation Administration (FAA), industry, and academia. It serves as the means to develop and implement cooperatively a rotorcraft technology plan and national strategy that can effectively address both civil and military rotorcraft needs.

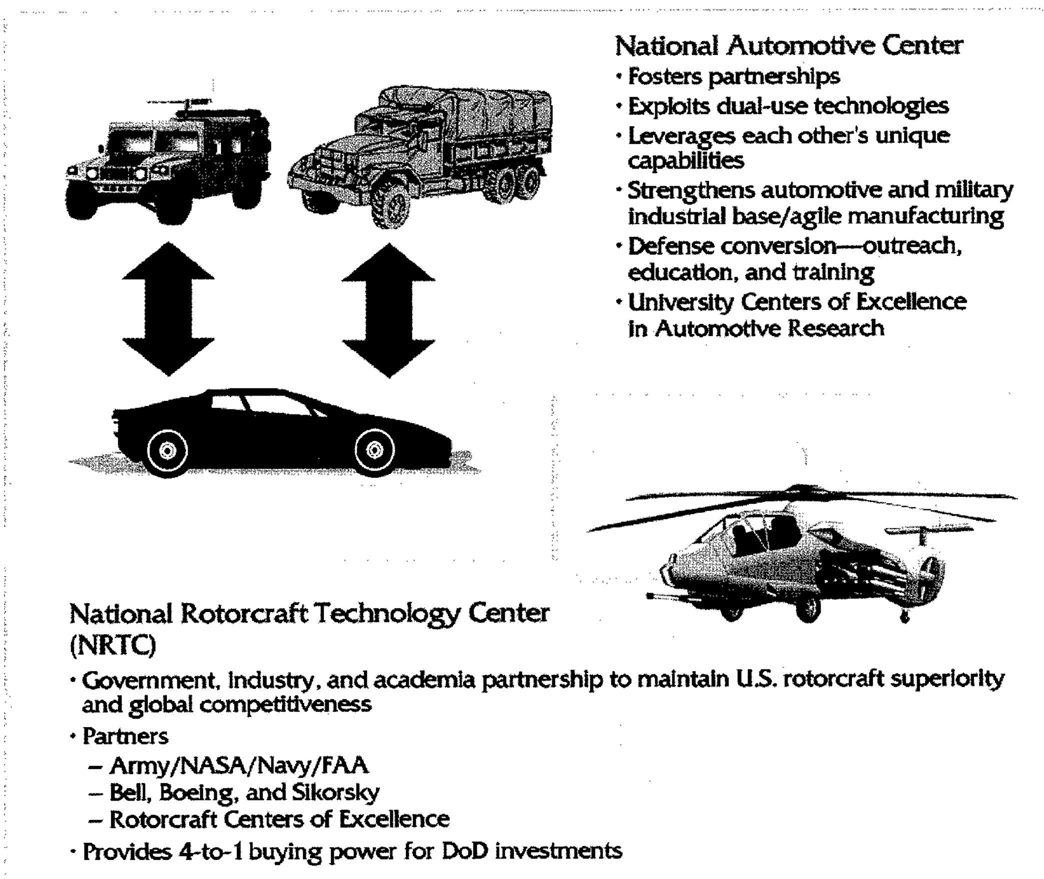


Figure I–16. Dual-Use Technology

The industry takes a proactive role in defining and performing the technology tasks to be undertaken through the Rotorcraft Industry Technology Association (RITA), a nonprofit corporation. The technology developed is shared among RITA members. The RITA program, with its near-term focus, is complemented by and continuously coordinated with the Rotorcraft Center of Excellence Program (performed by academia), which has a long-term focus.

University Research Centers

Army policy is to foster basic research objectives by leveraging research programs in academic institutions. To accomplish this the Army sponsors research through the Army Center of Excellence Program and through the DoD University Research Initiative. Through these programs the Army promotes active research participation with more than 20 American universities (Chapters V and VII).

Small Business Innovation Research

The Army has revised and strengthened the Small Business Innovation Research (SBIR) program to better leverage and support this innovative, entrepreneurial sector of our economy. The SBIR process (for companies with fewer than 500 employees) is as follows:

- Three-phase program
  - Phase I—Technical feasibility (6 months, $100,000 maximum)
  - Phase II—R&D effort (2 years, $750,000 maximum)
  - Phase III—Commercialization (no SBIR funds used)
- Department of the Army (DA) review/selection process
- $90–$100 million/year
- Gap between Phase I and Phase II efforts reduced by SBIR evaluation board; time reduced since 1994 for Phase I—4 months versus 7–8 months; Phase II—6 months versus 8–12 months. Efforts are under way to further reduce the gap between Phase I and Phase II.

Many Army S&T programs are conducted jointly or in coordination with the Air Force, the Navy, the Defense Advanced Research Projects Agency (DARPA), and other defense agencies assisted by Project Reliance. Other government agencies leveraged by the Army include NASA and the Department of Energy (DOE) National Laboratories.

Outside the United States, the Army seeks potential opportunities to increase the effectiveness of technology development through the sharing of research, development, test and evaluation (RDT&E) resources with NATO and major non-NATO allies. One example is the Future Scout and Cavalry System (FSCS) being developed jointly by the United States and the United Kingdom. These joint and interagency programs are discussed in Chapter VII and Annex E.

TECHNOLOGY TRANSITION

The number of major weapon system new starts will decrease substantially the rest of this decade, while increased reliance will be placed upon technology insertion into existing systems via such upgrading mechanisms as engineering change proposals (ECPs), product improvement proposals (PIPs), preplanned product improvements (P^3Is), and block improvement and multistage improvement programs (MSIPs).

Technology Demonstrations

A Technology Demonstration can serve as the means to demonstrate that a STO has successfully achieved its objectives, to highlight a new technical capability developed in the S&T community, or to assess the technical maturity of a capability identified outside of the S&T community. These programs, whose designation is at the discretion of the technical director, are a means to demonstrate a new technical capability that has potential application to an ATD, ACTD, or system acquisition program. Funded in either 6.2 or 6.3, these programs differ from ATDs and ACTDs in that they either are not conducted in an operational environment or do not involve experimentation with technology-driven operational issues. They can serve as the means to demonstrate that a STO has successfully achieved its

objectives, to highlight a new technical capability developed in the S&T community, or to assess the technical maturity of a capability identified outside of the S&T community.

There are two special types of TDs that greatly improve technology transition, ACTDs and ATDs.

Advanced Concept Technology Demonstrations

Advanced Concept Technology Demonstrations provide a mechanism for intense involvement of the warfighters while incorporation of technology into a warfighting system is still at an informal stage. This allows iterative change of both the system construct and the user's concept of operation without the constraints and costs that are incurred when the discipline of formal acquisition is involved. ACTDs are user oriented, even user dominated.

The ACTD has three driving motivations: (1) to have the user gain an understanding of the military utility before committing to large-scale acquisition, (2) to develop corresponding concepts of operation and doctrine that make the best use of the new capability, and (3) to provide limited, initial residual operational capabilities to the forces. ACTDs are of sufficient scope and scale to establish military utility. The operational unit is left with a residual capability for continued use for up to 2 years. This provides a significant improvement in the ability to refine the tactics and gain further insight into the potential utility and impact on doctrine. The ACTD process is shown in Figure I–17. All Army ACTD proposals must now have the approval of the commander of TRADOC. In the Army, ACTDs primarily involve system-of-systems demonstrations incorporating individual equipment developed under ATDs.

Formal requirements for the operational forces are typically generated during the ACTD after military utility has been demonstrated. The outcome of an ACTD is determined by the conclusions of the participating users. If the user is not prepared to initiate acquisition, the effort will be terminated. If, on the other hand, the user determines that the demonstrated concept should be brought into the forces, there are two possible avenues. If large numbers are required, the system should enter the acquisition process at whatever stage good judgment dictates. If only small numbers are required, it is preferable to modify the demonstration system appropriately and then to replicate it as needed. This latter avenue might apply to command, control, and communications (C^3), surveillance, and special operations equipment, as well as to complex software systems where evolutionary development and upgrading is preferred.

In FY98, the Army is participating in seven S&T-funded ACTDs, five as the lead service: Line-of-Sight Antitank (Chapter III and Figure I–18), Theater Precision Strike Operations (Figure I–19), Rapid Force Projection Initiative (Chapter III and Figure I–20), Combat Identification (Chapter III and Figure I–21), and Rapid Terrain Visualization (Chapter III and Figure I–22). The Army and Navy/Marine Corps jointly lead two ACTDs: Joint Countermine (Chapter III and Figure I–23) and Military Operations in Urban Terrain (Chapter III and Figure I–24). Most of these ACTDs are composed of one or more Army ATDs (described in Chapter III and Volume II, Annex B).

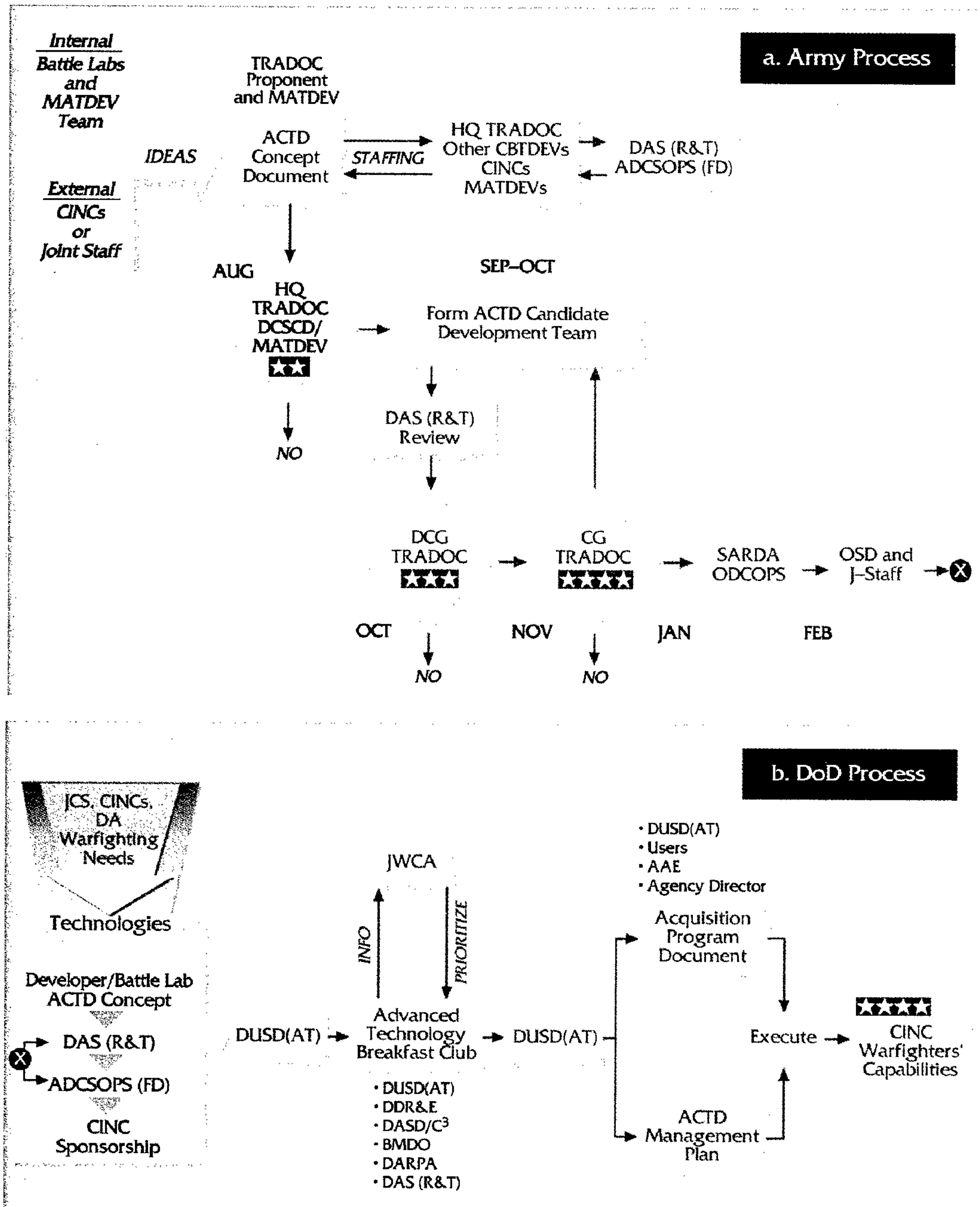


Figure I–17. ACTD Process

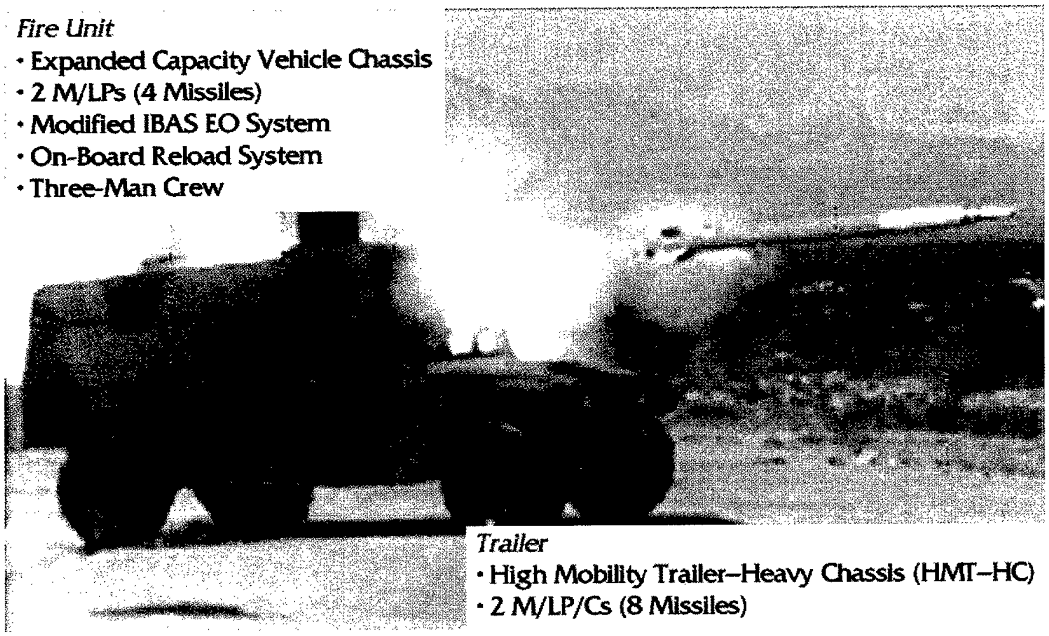


Figure I–18. Line-of-Sight Antitank ACTD

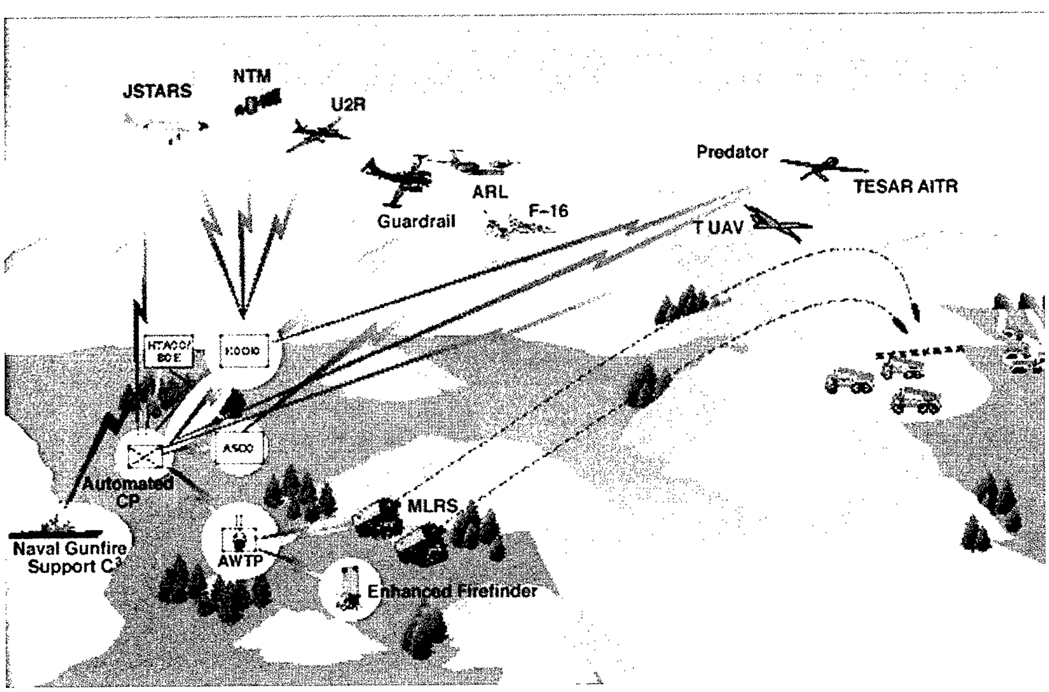


Figure I–19. Theater Precision Strike Operations ACTD

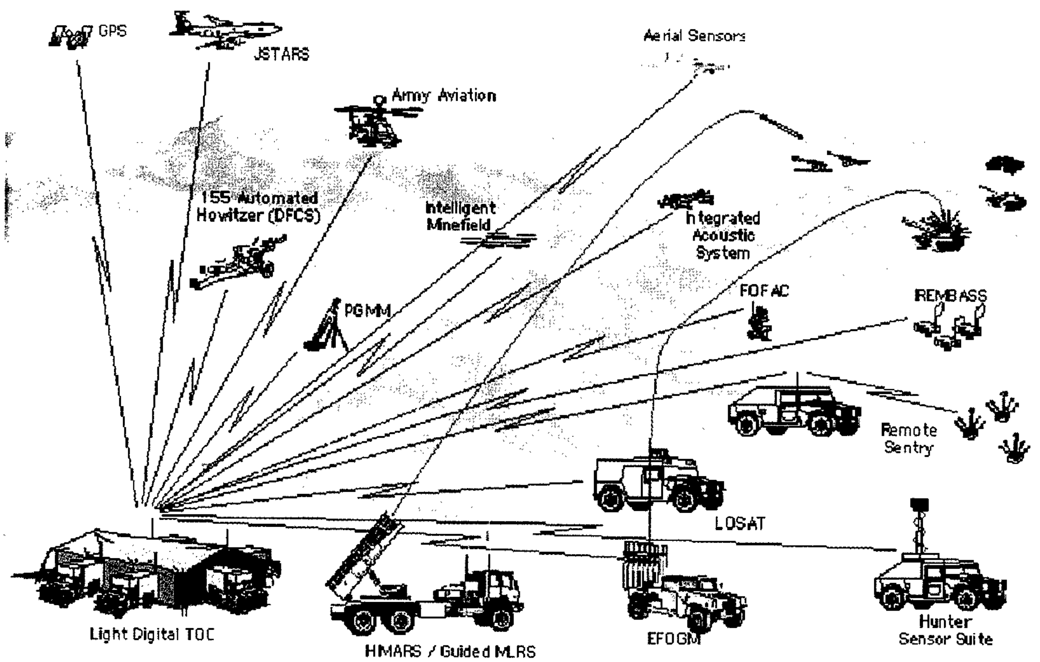


Figure I–20. Rapid Force Projection Initiative ACTD

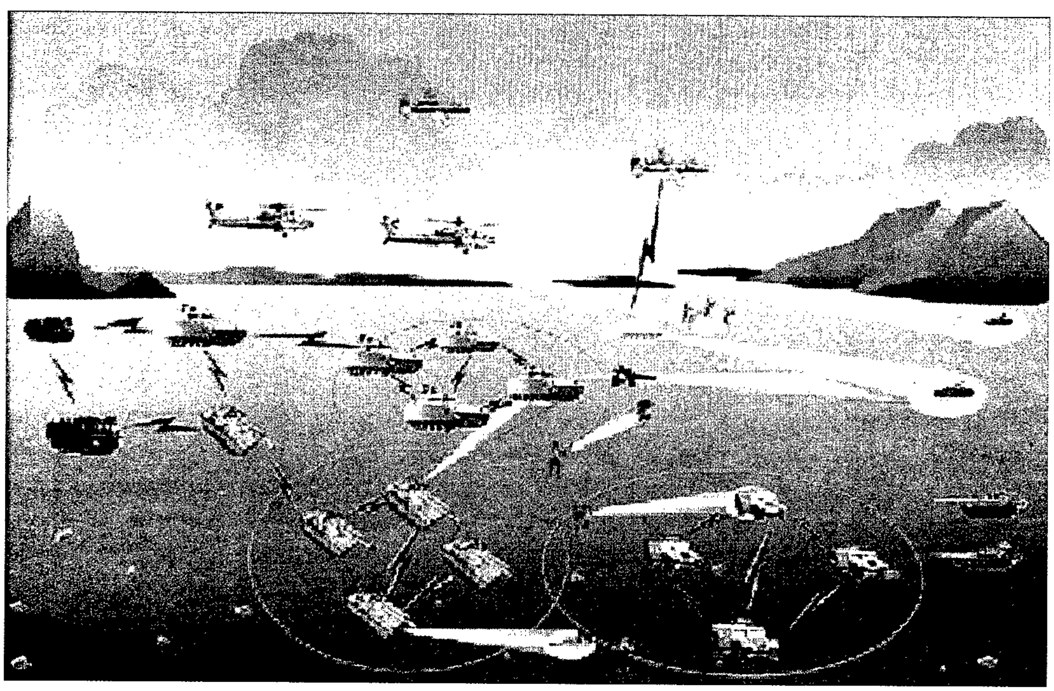
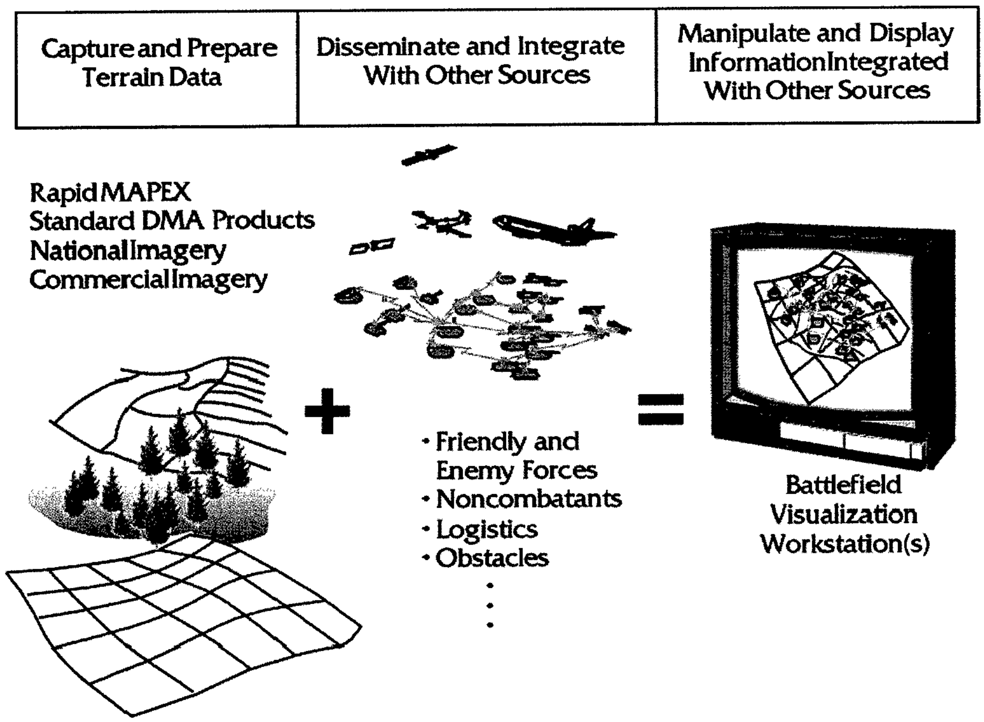


Figure I–21. Combat Identification ACTD



Supporting ATD: Battlespace C^2

Figure I–22. Rapid Terrain Visualization ACTD

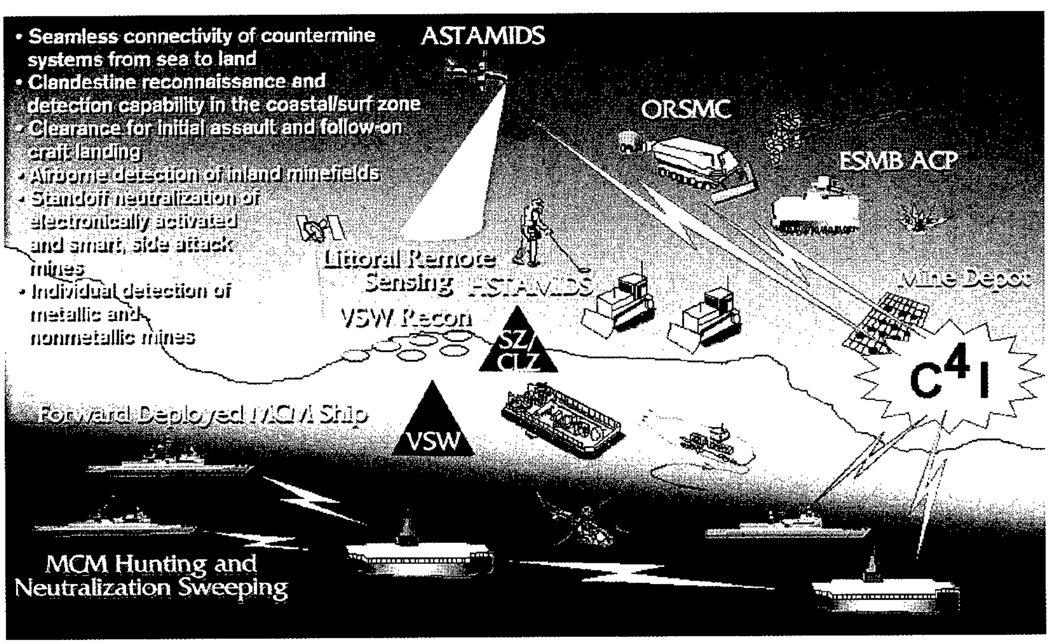


Figure I–23. Joint Countermine ACTD

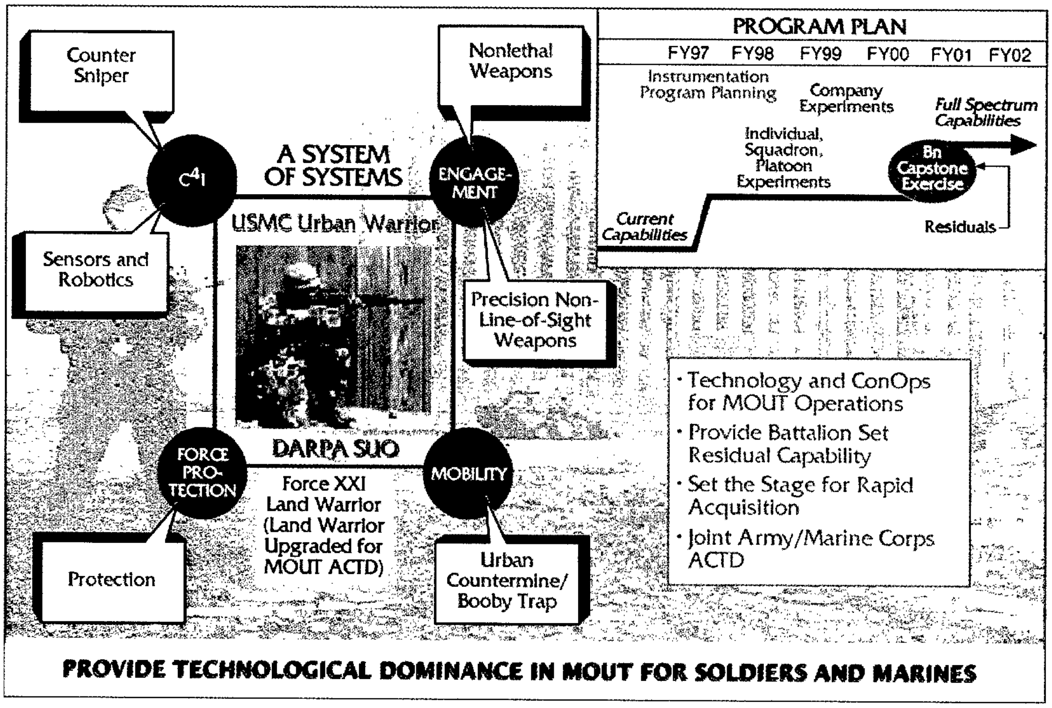


Figure I–24. Military Operations in Urban Terrain ACTD

Advanced Technology Demonstrations

Advanced Technology Demonstrations are technology demonstrations characterized by:

- Being relatively large scale in resources and complexity but typically focused on an individual system or subsystem.
- Operator/user involvement from planning to final documentation.
- Testing with soldiers in a real or synthetic operational environment.
- Exit criteria approved by both the materiel developer and TRADOC.
- Finite schedule, typically 5 years or less.
- Having cost, schedule, and objective performance baselines in an Advanced Technology Demonstration Management Plan (ATDMP) approved by the Deputy Assistant Secretary for Research and Technology (DAS(R&T)).

Each ATD is designed to meet or exceed exit criteria agreed upon by the warfighter and ATD manager at program inception. These must be met before the technology in question can transition to development. The ATD approval process is shown in Figure I–25.

ATDs seek to demonstrate the potential for enhanced military operational capability or cost effectiveness. Active participation by a TRADOC school, as well as the materiel developer, is required throughout the demonstration. At least one demonstration at a TRADOC battle lab, as well as an advanced simulation, are required. This helps the TRADOC schools develop more informed requirements and the materiel developer reduce risk prior to the initiation of full-scale system development. Table I–1 shows the crosswalk of the ongoing ATDs with the *Army Modernization Plan* annexes, and STOs (see also Volume II, Annex A and Chapter III).

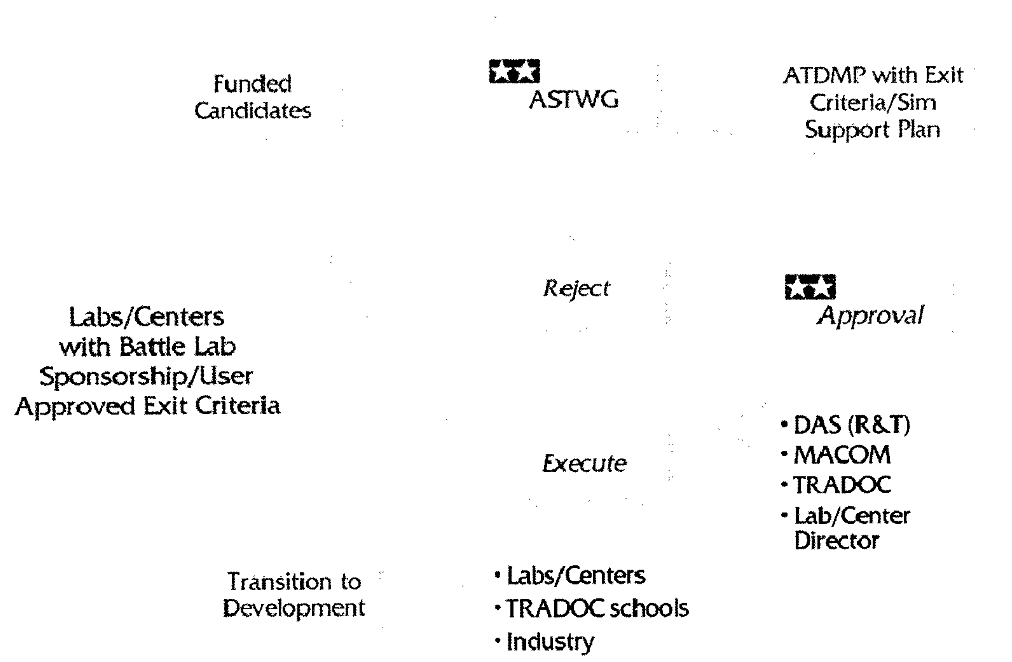


Figure I–25. Army ATDMP Approval Process

Table I–1. Correlation Between Ongoing Army ATDs and the *Army Modernization Plan*

ATD	*Army Modernization Plan* Annex Section		ASTMP Description Section	STO
	Primary	Secondary		
Rotorcraft Pilot's Associate	Aviation	IEW	III–D	III.D.01
Battlefield Combat Identification	C^4	IEW, Combat Maneuver, Aviation	III–E	III.E.07
Digital Battlefield Communications	C^4		III–E	III.E.09
Composite Armored Vehicle	Combat Maneuver		III–G	III.G.01
Target Acquisition	Combat Maneuver		III–G	III.G.08
Enhanced Fiber-Optic Guided Missile	Combat Maneuver	IEW	III–H	III.H.03
Precision-Guided Mortar Munition	Combat Maneuver	Fire Support	III–H	III.H.04
Objective Individual Combat Weapon	Combat Maneuver		III–I	III.I.01
Guided Multiple Launch Rocket System	Combat Maneuver		III–N	III.N.11
Vehicular-Mounted Mine Detector	Combat Maneuver		III–M	III.M.08
Direct Fire Lethality	Combat Maneuver		III–G	III.G.10
Integrated Biodetection	NBC		III–K	III.K.03
Multispectral Countermeasures	Aviation		III–D	III.D.13

Table I–1. Correlation Between Ongoing Army ATDs and the *Army Modernization Plan (continued)*

ATD	*Army Modernization Plan* Annex Section		ASTMP Description Section	STO
	Primary	Secondary		
Air/Land Enhanced Reconnaissance and Targeting	Aviation		III–D	III.D.14
Battlespace Command and Control	C^4		III–E	III.E.06
Future Scout and Cavalry System	Combat Maneuver		III–G	III.G.14
Multifunction Staring Sensor Suite	Combat Maneuver		III–H	III.H.15
Mine Hunter/Killer	Combat Maneuver		III–M	III.M.09
Tactical Command and Control Protect	IEW		III–F	III.F.09
Multimission/Common Modular Unmanned Aerial Vehicle Sensors	IEW		III–F	III.F.06

Horizontal Technology Integration

As defined by the Army's Horizontal Technology Integration (HTI) General Officer Working Group charter, HTI is the application of common enabling technologies across multiple systems within a force to increase force effectiveness. HTI allows the Army to lower R&D costs and development time and to obtain lower unit production costs by procuring larger quantities of the same subsystem for different weapon systems. The Army also benefits from a common logistics base for the same subsystems on multiple platforms. Key technologies under this concept include the 2nd Generation FLIR, Battlefield Combat Identification systems, Digitization, and Survivability Suite of Enhancement systems. Other initiatives under consideration include integrated power management, tactical lasers, and the advanced diagnostics improvement program.

New STOs and ATDs will consider and address HTI opportunities to ensure maximum potential platform applications. Leveraging the STOs and ATDs will facilitate the incorporation of HTI solutions in future system developments and P^3I efforts.

Acquisition Reform—The Fast Track Program

In recent years, it has become clear that significant reform in the technology acquisition procedures within DoD is necessary to modernize land, sea, and air forces in a timely and affordable manner. A principal reform under way in Army S&T is the Fast Track ATD policy, implemented to accelerate the Army's acquisition of selective, high-value, high-priority technology developed within the Army S&T program (Figure I–26). The policy has been developed within existing Army structures and organizations and is compatible with and supports *Federal Acquisition Regulation* and *DoD/Army Acquisition Policy (DoD 5000.1, DoD 5000.2–R,* and *AR 70–1).*

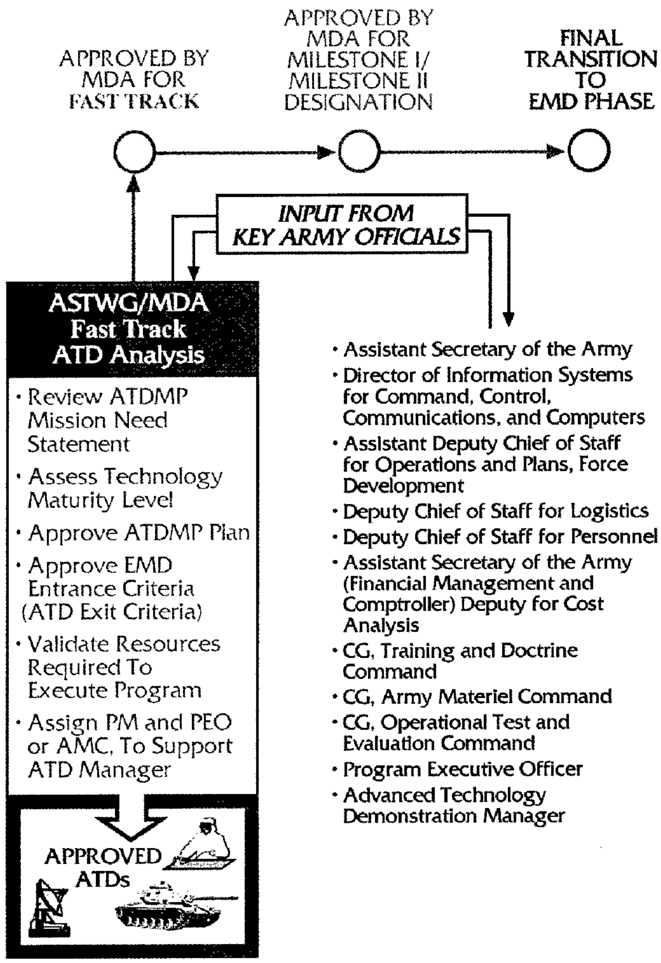


Figure I–26. Fast Track Acquisition Program

Specifically, the Fast Track program designates certain selected ATDs for increased management attention. To be selected, an ATD must involve technology that is sufficiently mature that it (1) can be demonstrated during a 6.3 ATD program with moderate risk, and (2) is a likely candidate for skipping the program definition and risk reduction (PDRR) phase entirely and transitioning directly to EMD, which is already funded in the POM. If these "likelihoods" are realized, a Fast Track approach can result in measurable time and cost savings.

The Fast Track process focuses on synchronizing technology demonstrations with the acquisition process to ensure a quicker transition to EMD for high-priority programs. On average, only one Fast Track ATD candidate per year will be recommended by the ASTWG. To establish a Fast Track ATD program, the ASTWG recommends Fast Track candidates to the Milestone Decision Authority (MDA) for approval. Fast Track designation is contingent upon sufficient funding in the POM to advance the technology to an MS I/II decision, through EMD, and into production.

Fast Track ATD candidates must have a Mission Need Statement (MNS) and an Advanced Technology Demonstration Management Plan (ATDMP) for Phase 0. The ATDMP does not limit itself to the plan for the demonstration but also describes transition planning for handover to a program manager to prepare for MS I/II, which occurs at the end of Phase 0.

Until the end of the ATD, requirements remain flexible. The ATD assists TRADOC in understanding the "art of the possible" and provides the basis for finalizing requirements into an Operational Requirements Document (ORD) before the end of Phase 0.

Fast Track designation is not a guarantee of funding or of entry into EMD. An approved Fast Track program loses the Fast Track designation if program funding for EMD falls out of the POM/Extended Planning Period (EPP). At the end of Phase 0, the MDA can approve an MS I/II decision and entry into EMD or, if the ATD was not fully successful, approve entry into a program definition and risk reduction phase—or cancel the program. The Army is using the Fast Track policy to try to advance the Future Scout and Cavalry System (FSCS) ATD directly to the EMD phase (Figure I–27).

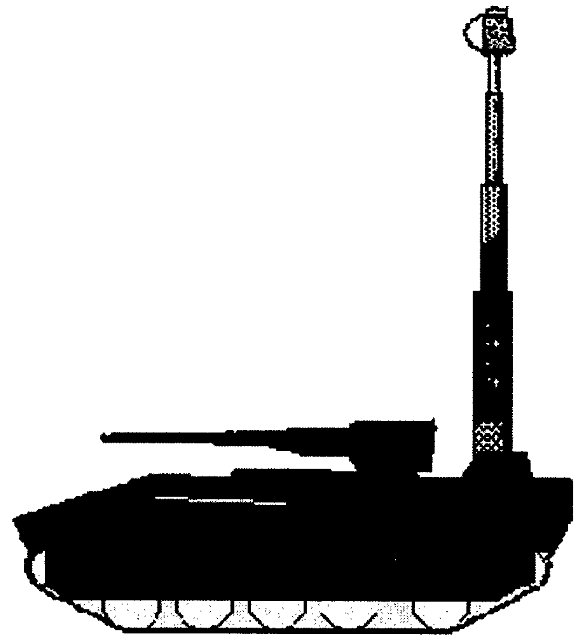


Figure I–27. Future Scout and Cavalry System

ARMY MODERNIZATION STRATEGY

Joint Vision 2010 (JV 2010) describes the operational concepts envisioned to achieve new levels of effectiveness in joint warfighting. It identifies advanced operational concepts that will result in dominance across the entire range of military activities—full spectrum dominance. *Army Vision 2010* (AV 2010) is the blueprint for the Army's contributions to the quality forces and operational concepts identified in JV 2010. Army elements will execute their warfighting responsibilities through a deliberate set of Patterns of Operation. These patterns serve to focus the many tasks that armies have always performed in war and other military operations, and they align with the JV 2010 operational concept. The relationship between JV 2010 concepts and AV 2010 patterns of operations is illustrated in Figure I–1 (above).

The overarching reason to modernize is to maintain a greater combat capability than a potential enemy might have. The Army must modernize to ensure that it is capable of responding to the Nation's needs, both today and in the future. The strategy determines which programs are necessary to modernize, to recapitalize (upgrade), or to defer until technology advances provide leap-ahead capability improvements. If the Army transforms too quickly, it risks acquiring capabilities that are "overkill" and not needed for the near-term strategic environment. Hasty transformation may also result in employing technologies that are not fully matured and may not be relevant over the long term. If the Army transforms too slowly, it risks losing its current position of combat overmatch capabilities.

Today, Army modernization investments account for just 14 percent of all DoD RDA. With these limited resources the Army must balance near-term readiness with far-term

investment. The systems that were fielded in the 1980s continue to serve the Army well today. With some improvements and technology insertions, many of these systems can continue to serve us into the 21st century. However, many will have reached or exceeded their useful life expectancy.

Information dominance through digitization of the battlefield provides essential capabilities required by JV 2010 to support the NMS; therefore, it is the Army's top priority. The *Quadrennial Defense Review* validated Army modernization objectives and increased funding for digitization and acceleration of the transformation of the U.S. Army Reserve and Army National Guard forces to fill critical capability shortfalls in combat support and combat service support forces. To realize AV 2010, the Army has decided upon a strategy that prioritizes investments over time. The strategy reflects the linkage to every required pattern of operation.

The strategy's approach encompasses near-, mid-, and far-term requirements. In the near term (98–03), priority on achieving information dominance by 2010 will be the focus of Army efforts. The Army will continue to allocate the necessary funding to sustain combat capability overmatch. In addition, it will fund research and development to support AAN. The Army is inserting technology to extend the lives and capabilities of many existing systems and older systems that are expensive to maintain and that provide minimal operational return. In the mid term (04–10), emphasis on information dominance will continue while the Army recapitalizes through technology insertion and replacement of aging equipment. For the far term (11–20), the Army will prioritize and focus its science and technology resources to leverage technology advances that will help to maintain decisive battlefield dominance for AAN. Through the far term, emphasis on Horizontal Technological Integration (HTI) will provide the warfighter with common, efficient, and high-payoff enabling technologies across multiple systems.

The five major goals of Army modernization are:

- Digitize the Army
- Maintain Combat Overmatch
- Sustain Essential Research and Development (R&D) and focus Science and Technology (S&T) on Leap-Ahead Technology for the *Army After Next*
- Recapitalize the Force
- Integrate the Active Component and Reserve Component.

Insights from the Army's Force XXI warfighting experiments and digitization efforts have demonstrated that information technologies integrated into an information dominance capability lead to increased force effectiveness. The Army Modernization Strategy focuses on digitization of the force while maintaining combat overmatch capabilities by making required improvements to only those platforms necessary to regain or sustain these capabilities.

Lessons learned in Army Warfighting Experiments (AWEs) have also identified the opportunities and benefits of technology integration that can provide advanced warfight-

ing capabilities. Reliance upon Science and Technology to provide the capabilities required for AAN is key to the modernization strategy. These capabilities provide a baseline for enhancements in information dominance, product improvements required for combat overmatch capabilities, and development of next-generation capabilities. By focusing S&T on leap-ahead technologies while sustaining essential research and development, the Army will be able to provide future capabilities for the AAN.

While the Army develops technologies required for physically agile AAN systems in the far term, it must field leap-ahead capability systems to bridge the gap caused by modernization deferrals. This will require lighter, faster, and more lethal weapons platforms for AAN that have the embedded information dominance capabilities that will have been added to Army XXI systems in the near and mid term. Figure I–28 displays synchronization of Army imperatives in the form of a spiral development process.

The *Army Modernization Plan* (AMP) describes how the budget supports the Army's requirements for research, development, and acquisition (RDA). The AMP balances fiscal realities with the knowledge that today's modernization is tomorrow's readiness. It consists of an overview, 15 mission area annexes, and a comprehensive glossary. These annexes are listed in Table I–2. Each annex provides the linkage of that mission area to the AV 2010 patterns of operation and includes a section on Essential Research and Development and Leap-Ahead Technology programs that highlight significant efforts important to the respective mission area. These descriptions directly correlate to the sections of Chapter III in the ASTMP. Figure I–29 shows how the Army S&T supports the modernization strategy.

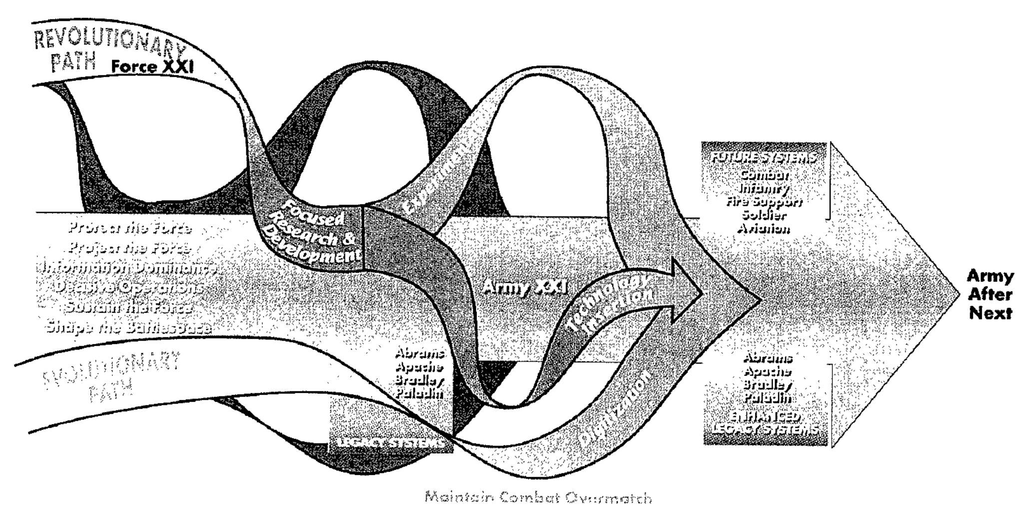


Figure I–28. Development of Full-Spectrum Dominance

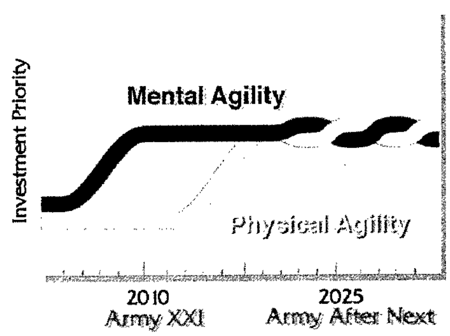
Table I–2. Army Modernization Plan Annex

Army Modernizatrion Plan Annex (Chapter III Section Title)	Reference
Force Structure	None
Soldier	III–I
Command, Control, Communications, and Computers	III–E
Mounted Forces, Close Combat Light, Engineer and Mine Warfare	III–G, III–H, III–M
Fire Support	III–N
Air and Missile Defense	III–L
Aviation	III–D
Nuclear, Biological, and Chemical	III–K
Command, Control, Communications, and Computers	III–E
Intelligence and Electronic Warfare	III–F
Tactical Wheeled Vehicles	None
Logistics	III–O
Combat Health Support	III–J
Training	III–P
Space	III–Q

New Modernization Strategy

Mid Term/Army Vision 2010
- Information dominance
- System upgrades to maintain overmatch

Far Term/Army After Next 2020 +
- Full-spectrum dominance
- New systems w/physical agility



E-FOG

S&T Strategy
- Information dominance
- Upgrade opportunities for combat overmatch
- Support for POMed systems that will enter development
- 7.8 Focus on reducing O&S costs and manufacturing costs of current and future systems

Figure I–29. Army S&T Supports Modernization Strategy

DEFENSE SCIENCE AND TECHNOLOGY STRATEGY

Technological superiority is a principal characteristic of our military advantage. It is the objective of the Department of Defense (DoD) Science and Technology (S&T) Program to develop options for future decisive military capabilities based on superior technology.

Dramatic changes affect our national security. In the next century the United States will face missions and adversaries that are unknown today, proliferation of sophisticated weapons, and the emergence of new kinds of warfare and operations other than war (OOTW) by nations and terrorist elements. Our armed forces will be smaller and field fewer weapon systems than at present.

The next century will also see the results of our current consolidation, diversification, and right-sizing of the defense industry. For an increasing number of technologies, commercial demand, not defense demand, will drive technical progress. DoD can both benefit from and contribute to a stronger U.S. industrial base by aligning defense technology development to complement commercial investment where appropriate. At the same time, we must continue to identify and support a well-defined set of defense-unique, defense-funded capabilities.

We are not the only nation with competence in defense science and technology. To sustain the lead which brought us victory during Desert Storm . . . recognizing that over time other nations will develop comparable capabilities, we must . . . invest in the next generation of defense technologies.

Defense Science and Technology Strategy
May 1996

Guiding Principles for S&T Management

The five guiding management principles cited in the *Defense S&T Strategy* have been adopted by the military departments and defense agencies as the centerpiece of the S&T management strategy. They are designed to place in the hands of U.S. operational forces the best mixture of capabilities possible, in the short and long term, by leveraging the best resources in DoD and the Nation:

- Transition technology to address warfighting needs
- Reduce cost
- Strengthen the industrial base
- Promote basic research
- Ensure quality.

Management and Oversight

The S&T program is planned, programmed, and conducted by the military departments and the defense agencies. The departments are responsible for training and equipping the military forces, and they use the S&T program to provide warfighting and system options for their components. The defense agencies are responsible for specified generic and cross-service aspects of S&T. They also execute designated programs in support of national security objectives. DARPA is charged with seeking breakthrough technology and with investing in technologies that are dual use, serving as bases for both defense and commercial applications.

The Director of Defense Research and Engineering (DDR&E) is responsible for the overall quality and content of the DoD S&T program. DDR&E, aided by the Defense Science and Technology Advisory Group (DSTAG) and the Reliance Executive Committee, ensures that the program responds to the needs of the U.S. military and to the national goals embraced in the program's vision. DDR&E assesses service/agency compliance with program guidance by means of Technology Area Review and Assessment (TARA) panels. Each TARA panel, composed primarily of outside technology experts and chaired by DDR&E technical staff, reviews the *Defense Technology Area Plan* (DTAP) prepared by joint expert teams of senior service and agency technologists. The process to update the DTAP, *Joint Warfighting Science and Technology Plan* (JWSTP), *Defense Technology Objectives for the JWSTP and DTAP,* and *Basic Research Plan* (BRP) is managed by the Reliance Executive Staff; the TARA process is managed by DDR&E. The relationship between the 10 defense technology areas and the 19 technology areas that are the basis for the taxonomy of Chapter IV of ASTMP is shown in Table I–3. The DTAP–JWSTP–DTO–TARA relationship and process instituted by the DDR&E with the DSTAG (Figures I–30 and I–31) are intended to make Defense S&T even more responsive to the warfighter and acquisition customers, increase the relevance and efficiency of the Defense S&T Reliance organization and process, and improve the overall effectiveness and efficiency of S&T strategic planning, programming, and assessment. The Deputy Under Secretary of Defense (Advanced Technology) is responsible for creation and oversight of ACTDs. Figure I–32 shows how Army and defense strategies relate to national plans and strategies.

Table I–3. Defense Technology Areas/Chapter IV Taxonomy

Defense Technology Area	Related Chapter IV Section
Air Platforms	Portions of Air Vehicles Portions of Aerospace Propulsion and Power
Chemical/Biological Defense and Nuclear	Chemical and Biological Defense
Information Systems Technology	Command, Control, and Communications Computing and Software Modeling and Simulation
Ground and Sea Vehicles	Ground Vehicles
Materials/Processes	Materials, Processes, and Structures Civil Engineering and Environmental Quality Manufacturing Science and Technology

Table I–3. Defense Technology Areas/Chapter IV Taxonomy (continued)

Defense Technology Area	Related Chapter IV Section
Biomedical	Medical and Biomedical Science and Technology
Sensors, Electronics, and Battlespace Environment	Sensors Electron Devices Battlespace Environments
Space Platforms	Portions of Air Vehicles Portions of Aerospace Propulsion and Power
Human Systems	Human Systems Interface Individual Survivability and Sustainability Personnel Performance and Training
Weapons	Conventional Weapons Electronic Warfare/Directed Energy Weapons

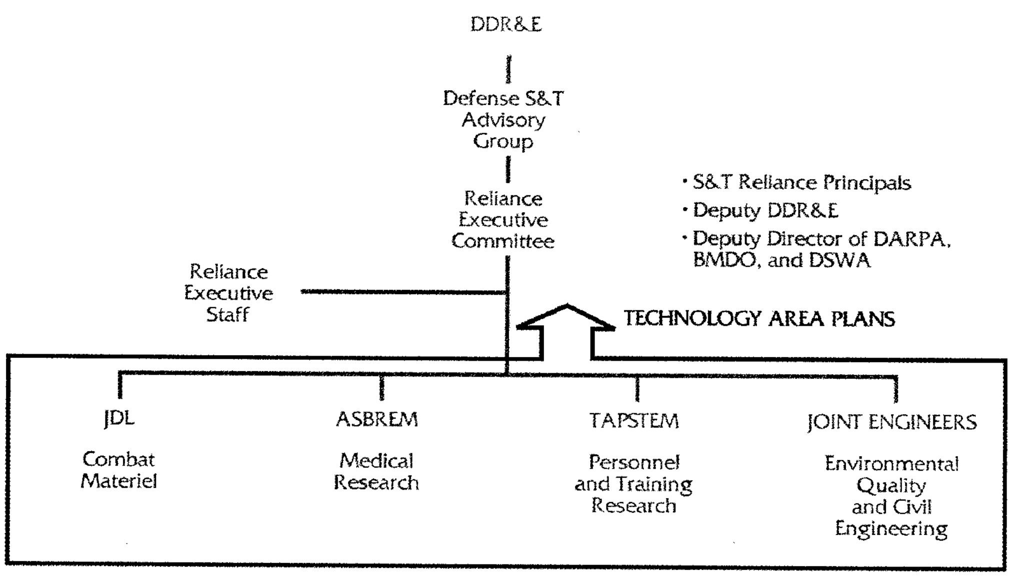


Figure I–30. Defense S&T Management and Reliance

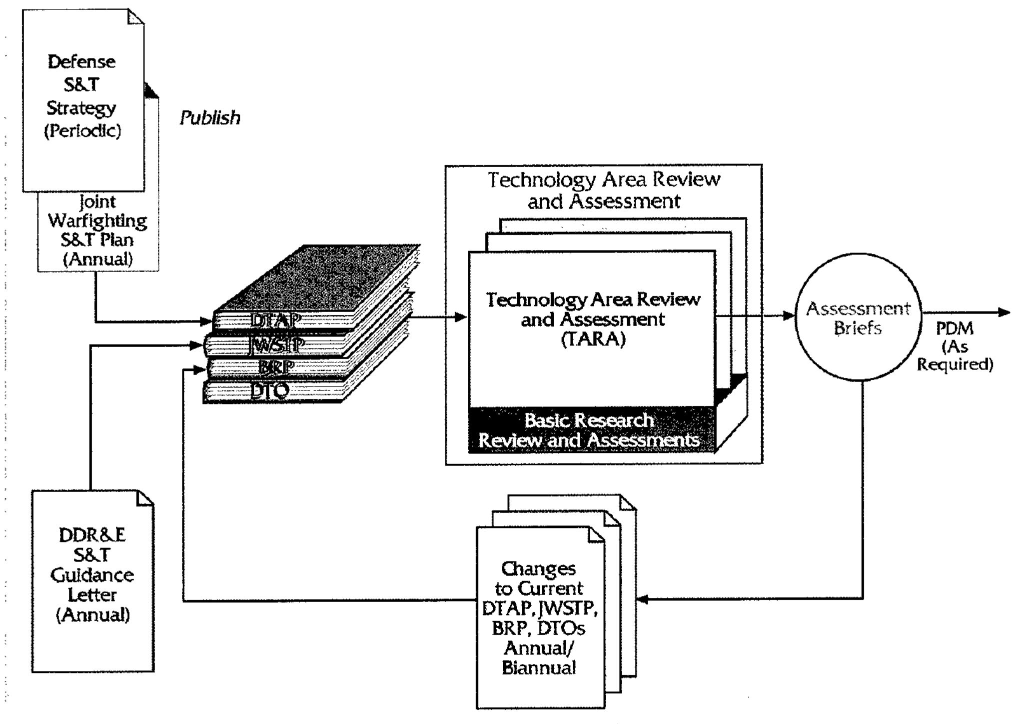


Figure I–31. Strategy, Planning, and Assessment Flow Diagram

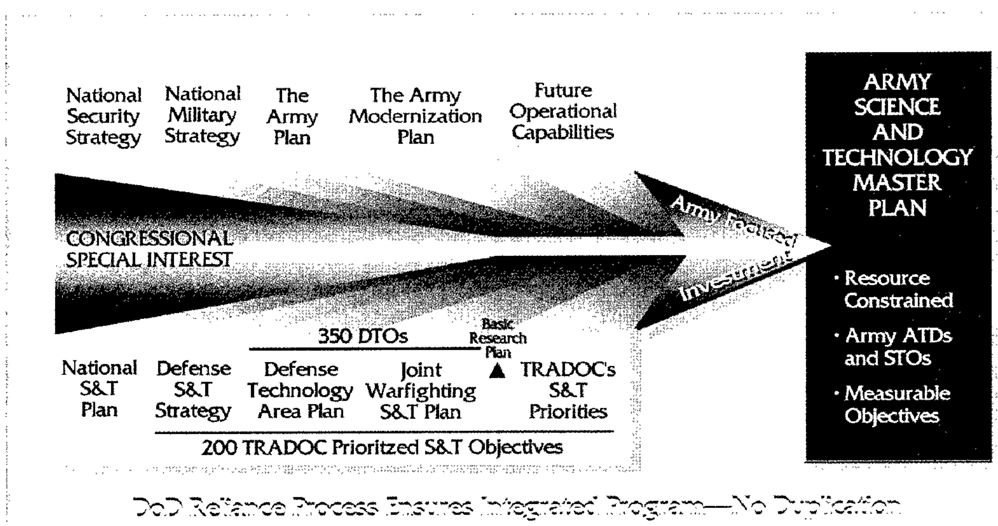


Figure I–32. Army S&T Vision and Strategy

Joint Chiefs of Staff Future Warfighting Capabilities Requirements

Military needs must determine what aspects of S&T the DoD pursues, and with what priority. It is the warfighter who enunciates those needs in this post-cold-war environment of widespread local warfare, potential for major regional conflicts, proliferation of weapons of mass destruction, and peacemaking operations. The JCS have identified 10 future joint warfighting capabilities (JWCs) most needed by the U.S. combatant commands. These needs, coupled with technological opportunity, guide S&T:

Information Superiority combines the capabilities of intelligence, surveillance, and reconnaissance (ISR) and command, control, communications, computers, and intelligence (C^4I) to acquire and assimilate information needed to dominate and neutralize adversary forces and effectively employ friendly forces. It includes the capability for near-real-time awareness of the location and activity of friendly, adversary, and neutral forces throughout the battlefield area. It also includes a seamless, robust C^4 network linking all friendly forces to provide common awareness of the current situation throughout the battlefield area. Information superiority encompasses information warfare—that is, the capability to affect an adversary's information, information-based processes, information systems, and computer-based networks while defending one's own information, information-based processes, information systems, and computer-based networks.

Precision Force is the capability to destroy selected targets with precision while limiting collateral damage. It includes precision guided munitions, surveillance, targeting capabilities, and the "sensor-to-shooter" C^4I capabilities necessary for responsive, timely force application.

Combat Identification is the capability to differentiate potential targets as friend, foe, or neutral in sufficient time, with high confidence, and at the requisite range to support weapon release and engagement decisions.

Joint Theater Missile Defense is the capability to use the assets of multiple services and agencies to detect, track, acquire, and destroy enemy theater ballistic missiles and cruise missiles. It includes the seamless flow of information on missile launches and cruise missiles (before and after launch) within the framework of joint counterair operations by specialized surveillance capabilities, through tracking by sensors from multiple services and agencies, to missile negation or destruction.

Military Operations in Urban Terrain (MOUT) is the capability to operate and conduct military operations in built-up areas and to achieve military objectives with minimal casualties and collateral damage. It includes precise weapons, surveillance, navigation, and communications effective in urban areas.

Joint Readiness and Logistics, and Sustainment of Strategic Systems is the capability to enhance readiness and logistics for joint and combined operations. It includes capabilities for enhanced simulation for training; improved and affordable operations and maintenance (O&M) and life-cycle costs; mobility and sustainability (e.g., transportation support technologies, such as airlift, sealift and ground transportation); and near-term visibility of people, units, equipment, and

supplies that are in storage, in process, in transit, or in theater, linked with the ability to act on this information. It also includes sustainment of strategic systems, which is the capability to sustain and upgrade existing strategic systems and to engineer, design, and develop strategic systems, including maintaining system safety; reducing system O&M cost; reducing reliance on existing strategic systems with advanced computing, simulation technologies, and advanced diagnostics; and retaining the engineering core competency for retrofit and replacement of materials unique to strategic systems.

Force Projection/Dominant Maneuver is the capability for fast deployment and timely employment and maneuver of joint forces to rapidly dominate across the full range of military operations with minimal casualties. This capability supports requirements to rapidly deploy and employ a decisive force with minimal use of lift resources and forward-based requirements. It includes enhanced capabilities in operational and tactical maneuver, joint countermine, individual and platform mobility, situation awareness, sustained logistics support, reconnaissance and intelligence, and integration of air-, land-, and sea-based maneuver and weapon systems. Joint countermine is the capability for assured, rapid surveillance, reconnaissance, detection, and neutralization of mines to enable forced entry by expeditionary forces. It also includes the capability to control the sea and to conduct amphibious and ground force operational maneuvers against hostile defensive forces employing sea, littoral, and land mines. For land forces, dominance means the ability to conduct in-stride tempo operations in the face of severe land mine threats.

Electronic Combat is the capability to disrupt or degrade an enemy's defenses throughout the area and time required to permit the deployment and employment of U.S. and allied combat systems. It includes the capabilities for deceiving, disrupting, and destroying the surveillance and command and control systems as well as the weapons of an enemy's integrated air defense network; and the capabilities for recognizing attempts by hostile systems to track or engage.

Chemical/Biological Warfare Defense and Protection and Counter Weapons of Mass Destruction (WMD) is the capability to detect and evaluate the existence of a manufacturing capability for WMD, and to identify and assess the weapon capability of alert and launched WMDs on the battlefield to permit the appropriate level of counterforce and force protection to be executed promptly. It includes counterforce against hardened WMD storage and production facilities and the capability for standoff detection of biological agents—our single most pressing need. Capabilities in both point and standoff detection of chemical and biological agents, combined with the ability to assess and disseminate threat information in a timely manner, are critical to protecting fielded forces.

Combating Terrorism is the capability to oppose terrorism throughout the threat spectrum, including antiterrorism (i.e., defensive measures to reduce vulnerability) and counterterrorism (i.e., offensive measures to prevent, deter, and respond). This capability includes personnel protection, assault, explosive detection and disposal, investigative science and forensics, physical security and infrastructure protection, surveillance, and collection, and enhanced support to allied land, sea, air, and riverine forces in the form of improved detection, monitoring and tracking, intelligence and logistics communications, training, and planning.

OTHER S&T INITIATIVES

Advanced Concepts and Technology (ACT II)

The ACT II 6.2 program competitively funds industry at the $10–$20 million per year level to participate in TRADOC battle lab warfighting experiments. A more comprehensive explanation is presented in Chapters II and VII. ACT II highlights are:

- Funded simulation and field tests at battle labs
- New concept evaluation by the battle labs
- Proposals from industry/academia through annual broad agency announcements (BAAs)
- Contract management through lead research, development, and engineering centers (RDECs) supporting battle labs
- Funding (6.2)—$10–$20 million per year FY95–03.

Manufacturing Technology Objectives

A robust, well-focused S&T program is essential for the Army to achieve its goal to provide the warfighter with the most capable, advanced weapon systems. However, particularly in the current budget-constrained environment, even the most promising systems conceived and developed in the S&T program will never reach the field if they are too expensive to produce. This is because the manufacturing "cost-drivers" for a system are often not addressed until the system is ready for production. Typically, there is little or no incentive for industrial providers to implement changes in processes or technology to effect manufacturing cost reductions, so that "affordability of production" is an issue that rarely gets addressed early in the program cycle.

The Manufacturing Technology (MANTECH) program in budget category 7.8 offers an opportunity to address affordability in a serious way as early in the cycle as possible. The goal of MANTECH is to provide essential manufacturing technologies that will enable the affordable production and sustainment of future weapon systems. Beginning in FY98, the Army is implementing a new initiative to refocus and strengthen MANTECH. Using the STO construct as a model and the ASTWG process as a vehicle for moving the MANTECH program into the Army S&T mainstream, the Army has devised a MANTECH strategy in which MANTECH funds will be leveraged with the funds of multiple PMs to address a few selected cross-cutting manufacturing issues that promise maximum overall impact, preferably supporting several existing planned development programs.

At the heart of this strategy is the creation of a small number of Manufacturing Technology Objectives (MTOs), analogous to STOs, comprising general and specific objectives. MTOs will be managed by MTO managers and have designated PEO/PM customers. Each MTO will be planned for a 3–5-year period and funded at $1–$3 million per year. In addition, there also will be a number of manufacturing demonstrations (MDs) funded at the $0.3–$1 million per year level.

The Manufacturing Technology Technical Council (MTTC), which reports to the ASTWG, will review annually the MANTECH program and approve the MTOs as required. The MTOs approved by the MTTC will be forwarded to the ASTWG for final approval. Within the next several years, as the new MANTECH approach demonstrates that significant cost savings can be achieved with relatively small investments in manufacturing technology early in development, the Army leadership believes that there will be a reversal in the downward funding trend that has been associated with MANTECH in the recent past. In the future, MTOs, in addition to the two hundred Army STOs, will make up the centerpiece of the Army S&T program.

INFRASTRUCTURE

A major element of the Army strategy is a strong, viable, high-quality in-house research capability. Laboratories and centers are the key organizations responsible for technical leadership, scientific advancement, and support for the acquisition process, including a smart buyer function. The Army S&T organizational structure is illustrated in Figure I–33.

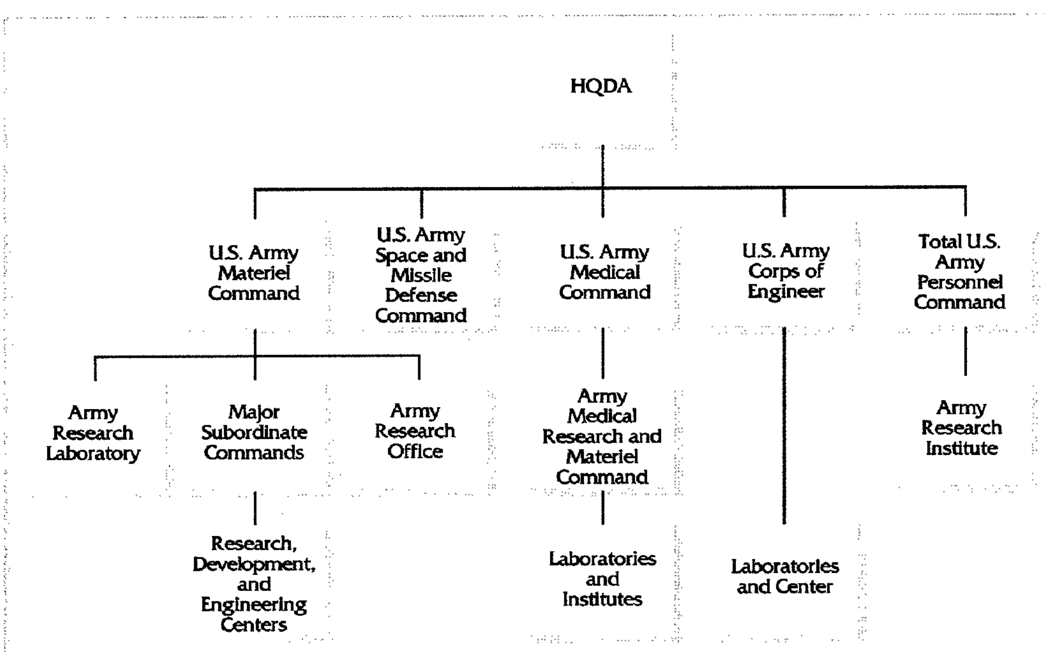


Figure I–33. Army S&T Organization

Facilities and Equipment—Essential Foundation for Success

The Army owns a multibillion dollar network of RDT&E facilities located at over 100 sites worldwide (see Chapter VI). The technological demands in many fields—including medicine, microelectronics, photonics, materials, and manufacturing processes—dictate the need for modern, excellent facilities. Consequently, the Army is consolidating special-

ized facilities, eliminating aging and technologically obsolete facilities, and using the capabilities of contractors and other military services. At the same time, Army RDT&E manpower is being drawn down. The new Walter Reed Army Institute for Research (WRAIR) facility is an example of long overdue modernization of in-house facilities that focuses on those unique capabilities that truly must be owned by the Army itself, consistent with Project Reliance and Base Realignment and Closure (BRAC) processes. The 1991 BRAC mandated organizational consolidation and geographic collocation of ARL at two main campuses: Adelphi and Aberdeen, Maryland. Construction has been completed on a new materials research facility at Aberdeen and new laboratory and office facilities at Adelphi to accommodate incoming personnel and maintain mission synergy.

In the future, the Army will use more automated equipment, computer-based research support, and technological networking of researchers to yield more work per scientist and engineer. This strategy will be very important as the Army reduces the size and changes the composition of its civilian work force. Advanced distributed simulation is compressing research and technology development cycle times. The use of physical simulation tools, computer modeling, and other highly automated systems is necessary to both product and manufacturing process technologies and is pivotal to the future of the Army R&D establishment. These issues are discussed further in Chapter VI.

People—The Key to the Future

Approximately 13,000 in-house personnel in 30 laboratories, centers, and institutes are funded by S&T. Working at a diversified set of facilities, ranging from solid-state physics laboratories to outdoor experimental ranges, they conduct research, technology development, "smart buyer," and product support activities for the total Army. Highly motivated, competent, well-trained people are essential to the success of the Army S&T strategy. Keeping the in-house work force technically competent in a rapidly changing environment is a major objective for the future. The DoD Laboratory Quality Initiative (LQI) allows revised procurement rules and investment in facilities that will assist in meeting the challenge.

Army S&T Laboratory Personnel Demonstration Projects

In 1994, Congress recognized the challenges facing DoD in its efforts to improve the recruitment, retention, and utilization of laboratory personnel. As a result, the National Defense Authorization Act for FY95 (Public Law 103.337) authorized laboratories designated by DoD as S&T reinvention laboratories to undertake personnel demonstration projects relating to qualifications, recruitment and appointment of personnel, classification and compensation, assignment, reassignment and promotions, discipline, incentives, hours of work, methods involving employees in labor organizations, and methods of reducing staff and grade levels.

The Army has 19 R&D organizations designated as S&T reinvention laboratories, each with authority to develop its own plan. Five of these organizations—ARL, U.S. Army Medical Research and Materiel Command, the Corps of Engineers' Waterways Experiment Station, the U.S. Army Missile RDEC, and the U.S. Army Aviation RDEC—were selected as

Phase I participants. The personnel demonstrations for the U.S. Army Missile RDEC and the U.S. Army Aviation were effective October 1, 1997. The rest of the Phase I laboratories will obtain the authority to begin implementation of their demonstrations in early FY98. The remaining 14 S&T reinvention laboratories are in Phase II. Their plans are currently under development, with approval of their final plans anticipated for spring 1998. More than 13,000 engineers, scientists, and administrative and technical personnel will be covered by Army S&T reinvention laboratory personnel demonstrations.

These demonstrations are the first major steps in developing personnel systems specifically tailored to the Army's laboratories. The demonstrations go far in answering criticisms from the Defense Science Board and others that the current system is too slow, puts up administrative barriers, and is impossible to change. These projects streamline some processes and introduce new flexibilities. Broadbanding, pay for performance, and pay in excess of the GS–15 levels for critical S&T management positions provide comparability to features that have been available in the private sector for many years.

These demonstrations are critical to strengthening the foundation needed to recruit and sustain a strong 21st century laboratory workforce capable of solving the technical challenges facing the 21st century warfighter.

Demographic projections for college graduates indicate a declining number of engineers and scientists in the period to 2015. The Army is the DoD leader in Youth Outreach (Table I–4), Historically Black Colleges and Universities (HBCUs), and Minority Institutions (MIs) (Table I–5). Every university research center of excellence and federated laboratory is required to have an HBCU or MI partner who performs a significant amount of the research. Army stay-in-school and summer-intern programs have convinced many students to study science and engineering.

Table I–4. Youth Science Activities

Goals:
- Conduct, promote, and sponsor science, mathematics, and engineering education
- Promote competent and diverse technical workforce
- Implement Executive Order 12821 and 10 U.S.C. 2192 (b)

Programs:
- DoD Science and Engineering Education Panel
- Junior Science and Humanities Symposia
- Research and Engineering Apprenticeship Program (REAP)
- "Uninitiates" Introduction to Engineering (UNITE)
- Science and Engineering Apprentice Program (SEAP)
- International Mathematical Olympiad and Science and Engineering Fairs

Table I–5. Historically Black Colleges and Universities and Minority Institutions

Centers of Excellence:

- Advanced Distributed Simulation: Grambling State University
- Advanced Materials: Tuskegee University
- Advanced Fuel Cell and Battery Manufacturing Technology: Illinois Institute of Technology
- Science, Math, and Engineering Education: Contra Costa College, Morehouse College

Single Investigator Programs:

16 investigators at 11 institutions,including:

- North Carolina A&T State University
- Alabama A&M University
- University of Texas at San Antonio
- New Mexico State University

Collaborative Research Programs:

- U.S. Army High-Performance Computing Research Center Subcontractor: Howard University

THE ARMY LEGACY

The *Army Science and Technology Master Plan* describes the development and maturation of technologies for the Army's future systems and system upgrades. Indeed, it is this transition of technology into affordable systems and capabilities that makes the S&T program a sound investment. Over the last 60 years, Army R&D has developed and fielded a number of significant product and process technologies, some of which are highlighted in Table I–6. Figures I–34, I–35, and I–36 highlight some of the S&T contributions to Army aviation, tanks, and howitzers. The impact of these technologies on military operations has been significant. Army S&T products helped win the cold war, Operation Just Cause, and Operation Desert Storm. Beginning in the 1980s, past Army investments from basic science through subsystem components have made the United States the leader in night vision capability (Figure I–37). Today's investments will likewise lead to compact power for 21st century applications (Figure I–38).

Table I–6. Army R&D Accomplishments

1990s	
• Hypertonic saline dexton effectively resuscitates after significant hemorrhage; poses no hazard to renal function • CORE–LOC concrete armor unit for breakwaters • Full-color, thin-film electroluminescent, one-million-pixel, flat-panel display • Composite hull for armored vehicles • Produced enzymatically active human acetylcholinesterase using recombinant DNA techniques • Airborne standoff minefield detection system • Second-generation FLIR	• Food and Drug Administration licensure of halofantrine • Insects for biological control of problem aquatic plants • Rock rubble antipenetration shielding • Day/night, adverse-weather pilotage systems (D/NAPS) • Gene code in drug-resistant malaria strains analogous to that in human cancer cells resistant to anticancer drugs • Intrinsic chemical markers for food safety to validate the safety (i.e., sterility) of thermo-processed particulate foods
1980s	
• AIDS diagnostic and staging schemes published for wide usage • Resin-based, nontoxic skin decontamination kit fielded • Pretreatment, improved antidote, and anticonvulsant therapy for nerve agent poisoning • Ballistic-laser protective spectacles fielded	• High-precision missile terminal imaging • Mefloquine, antimalarial drug fielded • All-composite aircraft demonstrated • Image processing • Personnel selection, classification, and assignment for formation of volunteer Army • Wire strike protection system fielded
1970s	
• Reverse osmosis water purification fielded • Frequency-hopping radios • Fiber optics applications: fly-by-light, fiber-optic guided missile (FOGM), communications • Lightweight, flexible body armor	• Meals, ready to eat (MRE) • High-burn-rate, solid-rocket-fuel technology • First practical hit-rotor system demonstrated • Superlattice electronics • First-generation thermal imager fielded
1960s	
• Meningitis vaccine developed • Individual and vehicle ceramic armor • Inertial surveying for field artillery demonstrated • Freeze-dried compressed foods introduced • Fast Fourier transform developed	• Sulfamylon, an antibacterial cream, developed for treatment of burns • First starlight scope fielded • Laser rangefinder • Rubella virus (German measles) isolated • Laser semiactive guidance invented and demonstrated
1950s	
• Global standard for time measurement • Photolithographic process for printed circuit boards • First weather/communications satellites • Solar cells for satellites • Redstone rocket—Army first in space • Turbine power for helicopter fielded	• Dehydration/freeze drying of foods made practical • Mouth-to-mouth resuscitation developed • Image intensifier scope • T1–6A1–4V titanium alloy for aircraft developed
1940s	
• Iodine tables for individual water purification • First specific cure for typhoid fever • First synthetic quartz • ENIAC, first modern electronic computer • First supersonic wind tunnel	• Atomic bomb fielded • Helicopter first flown • Engine for first American jet fighter • Whole blood preservation • Proximity fuze

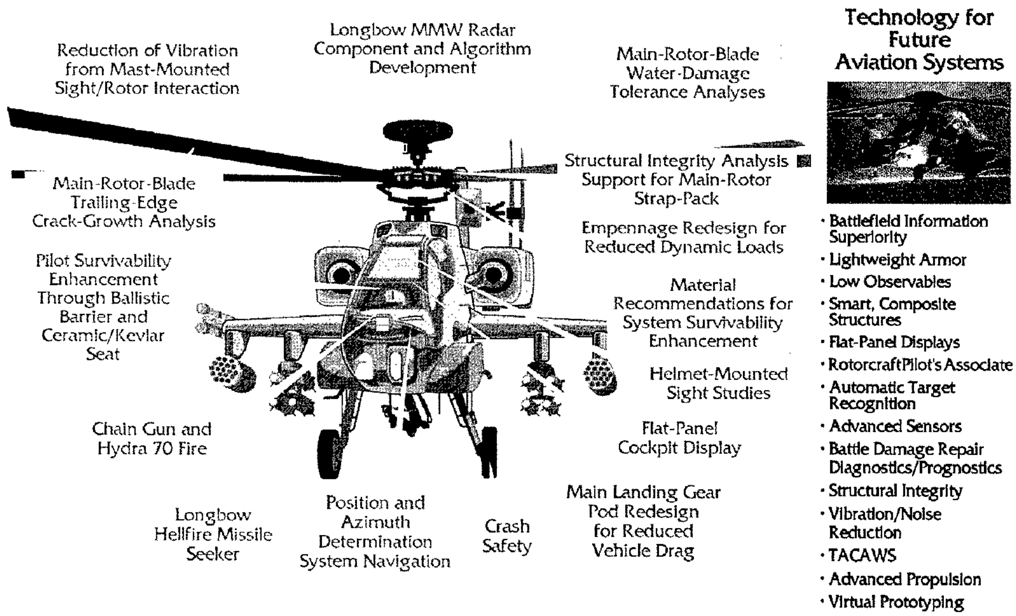


Figure I–34. Aviation—Past and Future

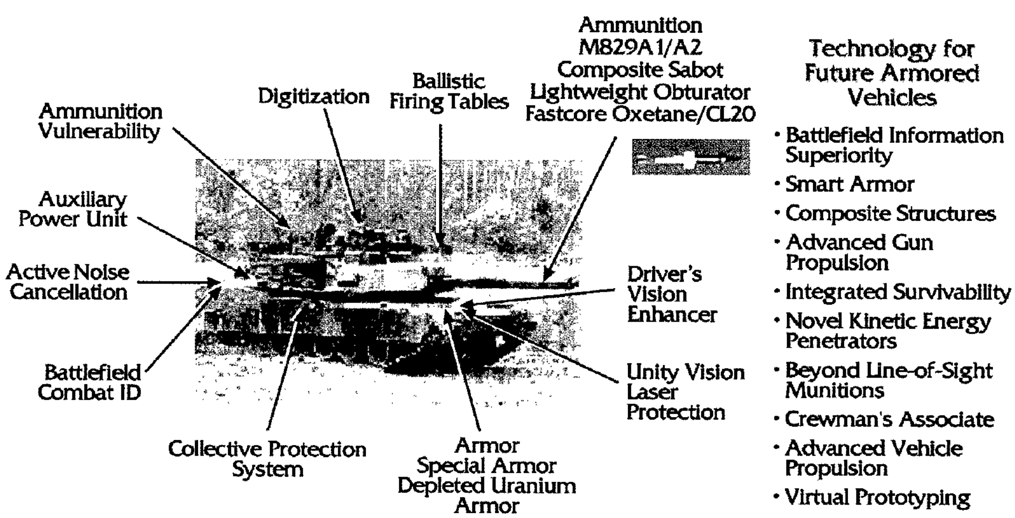


Figure I–35. S&T Contributions to Abrams Tank

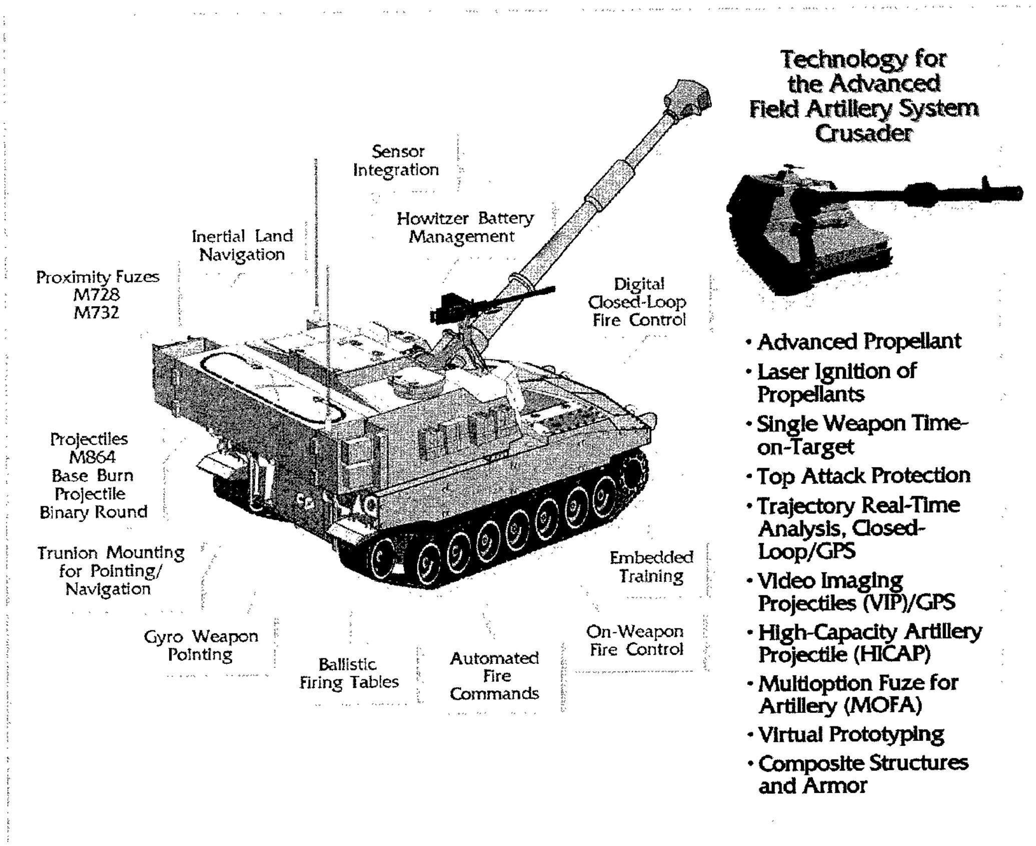


Figure I–36. Howitzers—Past and Future

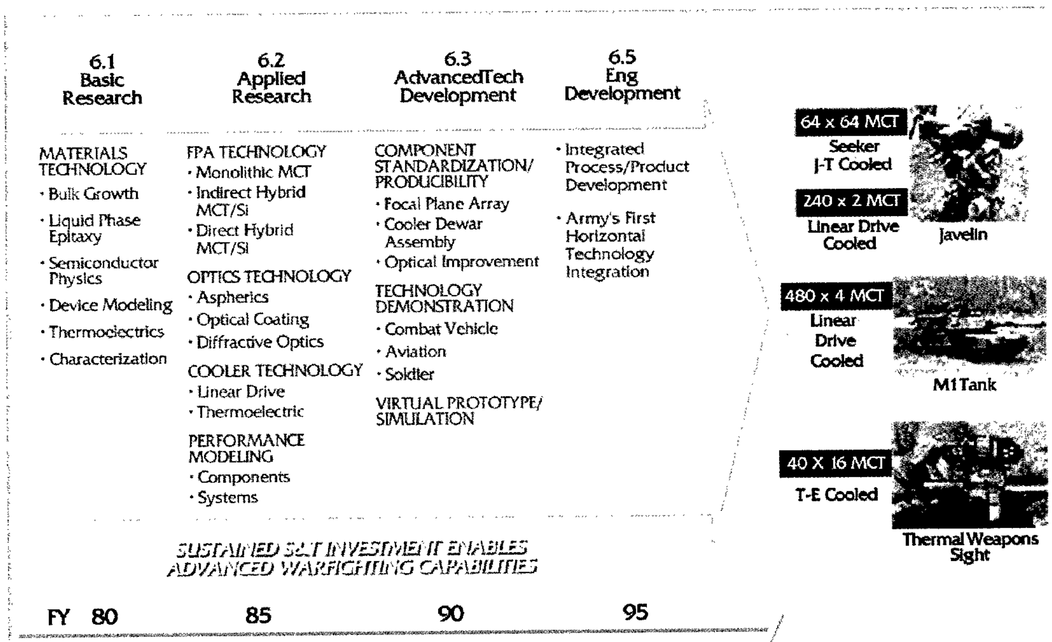


Figure I–37. Evolution of Second-Generation FLIR Technology

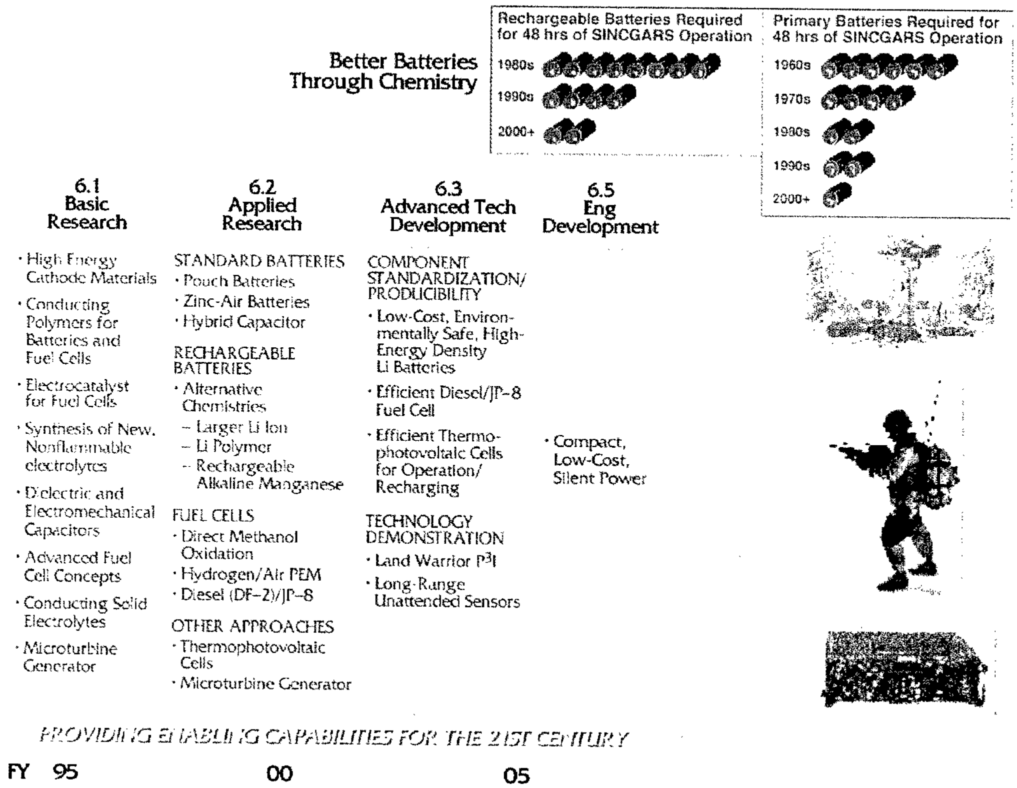


Figure I–38. The Future of Compact Power Technology

CONCLUSION

The *Army Science and Technology Master Plan* is approved by the Secretary of the Army and the Chief of Staff of the Army. It is the S&T roadmap for achieving AV 2010 and AAN. This plan is provided to government, industry, and academia to convey the Army's S&T vision, objectives, priorities, and corresponding investment strategy. This document is an explicit, resource-constrained Department of Army guide to funding priorities and the S&T program as a whole. "Resource-constrained" means the program activities discussed in this document are funded in the FY98 Army Appropriation and the FY99 President's Budget (FY99–03). The schedules and projected technical accomplishments reflect this level of funding.

It should also be noted that laboratory and center directors have sufficient flexibility, resources, and authority to initiate projects, explore promising avenues of research and development, and exploit opportunities as they are identified, beyond those discussed in this document. Budget reductions, however, continue to erode this flexibility so essential to technical discovery and support to the acquisition and field commanders. The Army's S&T strategy and plan include support to the DTAP, JCS Future Warfighting Capabilities, S&T Reliance, and cooperation with U.S. allies to pursue common goals.

Technological superiority is essential if a smaller Army is to be able to engage successfully in a wide variety of future conflicts with minimal casualties. With continued support, the Army S&T program will ensure affordable technological superiority, avoid technological surprise, and provide revolutionary warfighting capabilities for the AAN (Figure I–39 and Table I–7).

America's Army exists to fight and win our nation's wars. Today's Army is ready to accomplish this and any other task required. The Army has a vision that sustains this essence while accommodating enormous change with balance and continuity. Today's soldiers benefit from past commitments to a robust S&T program. Tomorrow's soldiers deserve no less.

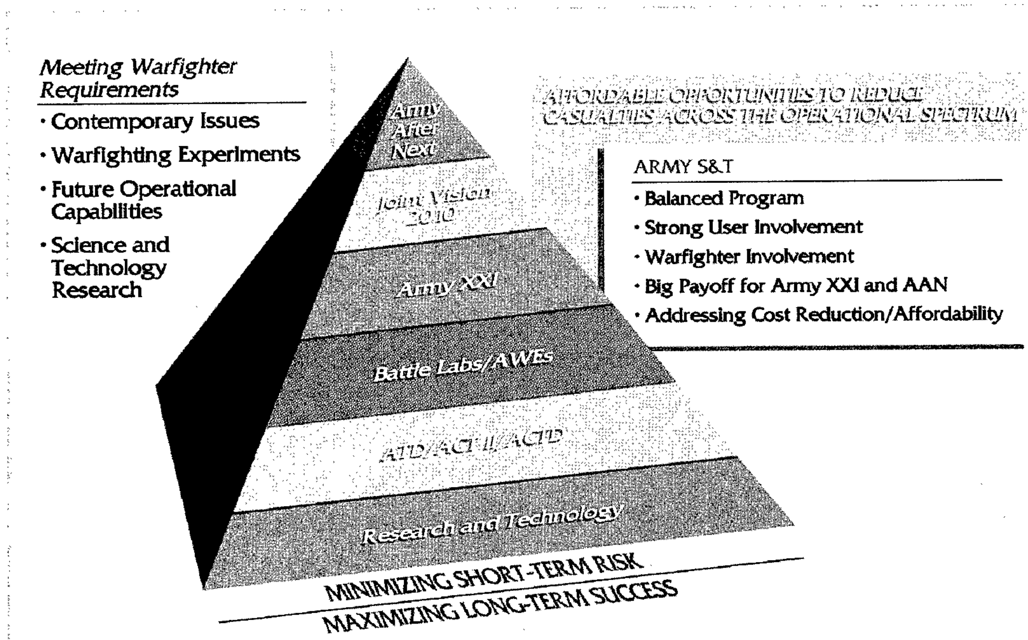


Figure I–39. S&T—Focused on the Warfighter

Table I–7. S&T Doing More for the Warfighter With Fewer Resources

S&T now includes:
• System-of-systems capability demonstrations
• ACTDs (large-scale field exercises and residual capabilities)
• Simulation technology to support how-to-fight demonstrations
• Concepts for battle labs (ACT II)
• Industrial partnerships (NAC and NRTC)
• Dual-use partnerships (DUAP)
• Federated labs (6.1)
• Environmental technology
• Producibility (integrated product and process design)
• Support to advanced warfighting experiments
• Technology for horizontal technology integration
• More complete technical risk reduction
• Acquisition reform via Fast Track (straight to EMD)
• Support for the *Army After Next*

CHAPTER II

TRAINING AND DOCTRINE COMMAND'S ROLE IN SCIENCE AND TECHNOLOGY

CONTENTS

CHAPTER II

TRAINING AND DOCTRINE COMMAND'S ROLE IN SCIENCE AND TECHNOLOGY

The Army is not static. It is vital and dynamic, and adapts to meet the future.

General Johnnie E. Wilson
Commanding General, U.S. Army Materiel Command

A. BACKGROUND

Battle laboratories were established in 1992 to experiment with changing methods of warfare in order to ensure that future generations of soldiers have the same battlefield edge our forces had in Operation Desert Storm and other recent operations. We have formed hypotheses concerning changing methods of operation and then conducted experiments using soldiers and leaders in increasingly realistic live, tactically competitive training environments. From this we are developing warfighting requirements for maintaining the edge on the battlefield.

The six original battle laboratories were designed to test battlefield dynamics that codify the aspects of warfighting that appear to have the greatest potential for change. They describe the need to:

- Increase lethality and survivability of early entry forces.
- Expand and dominate dismounted and mounted battlespace.
- Attack an adversary simultaneously in all dimensions throughout the battlefield.
- Command and move information in near-real time while on the move.
- Use and reuse scarce assets to sustain the force on the battlefield.

The success of the first battle labs led to the establishment of three new ones concerned with maneuver support, air maneuver, and space.

During the last 5 years, the battle lab process has been validated through six advanced warfighting experiments (AWEs) and a related series of How to Fight seminars and videos. The concept has been continuously updated and the output can be seen in Force XXI.

Figure II–1 shows battle laboratories and their locations.

B. TASK FORCE XXI ADVANCED WARFIGHTING EXPERIMENT

In March 1997, the Army conducted an AWE at the National Training Center (NTC), Fort Irwin, California. The purpose of the AWE was to test a hypothesis: *If* . . . information-age battle command capabilities/connectivity exist across all battlefield operating systems (BOSs) and battlefield functional areas (BFAs) for a brigade task force, *then* . . . enhancements in lethality, survivability, and operational tempo will be achieved.

The 1st Brigade Combat Team (BCT), 4th Infantry Division, deployed to the NTC in March 1997 with more than 5,000 soldiers organized in eight battalions, six companies, and a separate platoon. The eight-battalion force included a mechanized infantry battalion, a tank battalion, a light infantry battalion, two field artillery battal-

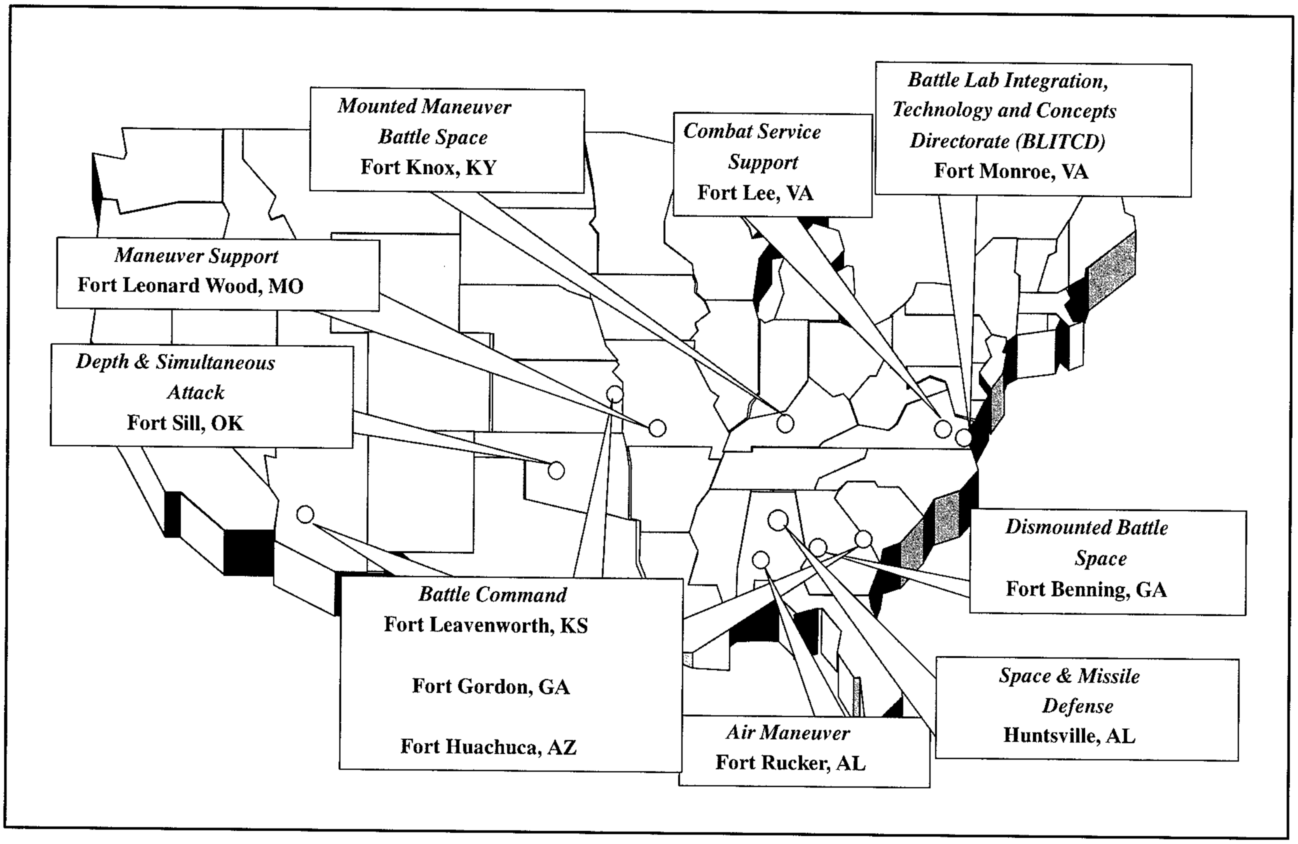


Figure II–1. Battle Laboratories

ions, a forward support battalion (FSB), and an aviation task force of two battalions.

The AWE involved 72 initiatives ranging from prototype and newly fielded equipment to organizational changes and concepts. Over 900 vehicles at Fort Hood, Texas, were equipped with over 5,000 pieces of equipment, including 1,200 appliqué computers.

Sixty new "digital" tactics, techniques, and procedures were introduced into the 1st BCT. From June until December 1997, the BCT trained at Fort Hood, beginning with the most basic classroom and hands-on training, progressing to platoon, company, and battalion lanes, culminating with a BCT exercise in December 1997. During this time, soldiers and leaders gained insights into new training methods, stressed technical updates and solutions, and experimented with concepts from the Training and Doctrine Command (TRADOC) pamphlet (T.P.) 525–5, *Force XXI Operations.*

After a shakeout phase at the Fort Irwin NTC, the 1st BCT underwent a 2-week, force-on-force exercise against a nondigitized but augmented and robust opposing force (OPFOR). The first week consisted of the standard missions that all units who train at the NTC undergo. This was done in an effort to compare performance data of digitized versus nondigitized units. The second week consisted of unrestricted, continuous operations across a much expanded battlespace, designed to gain insights into Force XXI operations. The Air Force, Marine Corps, and Special Operations Forces also participated.

One of the most powerful initiatives emerging from the task force AWE was situational awareness. Using appliqué computers and the tactical internet, unit commanders, small unit leaders, and individual vehicles were able to share information about both friendly and

enemy forces, reducing the historical fog of war. Such situational awareness helps answer the perennial questions:

- Where am I?
- Where is the enemy?
- Where are my buddies?

Knowing one's specific location, that of one's own forces, and that of the enemy's, allows commanders to make more informed battlefield decisions.

Many insights emerged from the task force AWE, across doctrine, training, leader development, organizations, materiel, and soldiers (DTLOMS). These insights will lead to refined training methods, doctrine, and organizations as the Army of Excellence transitions to Army XXI. The task force AWE also provided insights for recommending systems for the first digitized division. These insights will enable the senior leadership to make resource decisions for rapid acquisition of the most promising initiatives.

The AWEs completed to date and the "How to Fight" seminars have resulted in a better understanding of Force XXI. What follows is a description of Force XXI as we understand it today. The discussion will describe the characteristics of Force XXI and its anticipated patterns of operation.

C. WHERE DO WE GO FROM HERE?

1. Division XXI Advanced Warfighting Experiment

In November 1997, the Army conducted a Division AWE at Fort Hood, Texas. This was a constructive simulation involving the 4th Infantry Division, III Corps, and many of the reserve component war trace headquarters.

The purpose was to test the connectivity and interoperability of the Army Tactical Command and Control System and to validate the division design using a synthetic theater of war (STOW). In addition, the scenario developed for this experiment allowed the focus to be on leveraging technology to protect, sustain, shape, and conduct decisive operations so as to create greater opportunities for maneuver in a nonlinear, greatly expanded battlefield environment.

The results of the division AWE are expected to contribute to a decision about the final objective division design in February 1998.

Task Force XXI is a step along the path, fed by NTC 94–07, and incorporating lessons learned from '95/96 AWEs. The operational concepts were derived from T.P. 525–5, Force XXI Operations, and Force XXI Division Redesign. Decisions fed further experiments, the most recent is the Division XXI AWE. The Experimental Forces (EXFOR) brigade design was refined and experimented with again as a live brigade in Division XXI AWE, consisting of an armor battalion, mechanized battalion, engineer battalion, and an aviation task force.

The primary objective of the division AWE was to validate the division design by using STOW capabilities, digitizing the division headquarters, executing division–brigade digitized command, control, communications, and intelligence (C^3I) interfaces/connectivity, and validating tactics, techniques, and procedures (TTPs). This experiment executed operations simultaneously: brigade (BDE) live, BDE virtual, and BDE constructive to gain insights on echelons above division (EAD) and joint digitized operations. The experiment culminated with a digitized battle command training program (BCTP) Warfighter in the first quarter of 1998 (November 1997).

The division AWE examined:

- *How to organize*—combinations of combat, combat support, and combat service support units.
- *How to fight*—tactics, techniques, and procedures.
- *How to command*—optimal processes for each battlefield function and objective (expand battlespace, continuous opera-

tions, noncontiguous operations, and joint operations).

D. SCIENCE AND TECHNOLOGY INTEGRATION

TRADOC's role in the Army's science and technology (S&T) program begins as the originator of warfighting requirements for the Army. From there, TRADOC directly influences the spending of half the S&T budget in Basic Research (6.1), Applied Research (6.2), and Advanced Development (6.3) through the application of future operational capabilities (FOCs) in:

- Strategic Research Objectives (SROs) selection.
- S&T reviews.
- Science and Technology Objectives (STOs).
- Advanced Concept and Technology II (ACT II).
- Advanced Technology Demonstrations (ATDs).
- Advanced Concepts and Technology Demonstrations (ACTDs).

1. Basic Research (6.1)

TRADOC is involved in SROs through the development of the *Army After Next* (AAN). The SROs look deep into the future (2025) to develop those research areas today that are anticipated as necessary in the future.

2. Applied Research (6.2)

TRADOC influences the 6.2 arena in three vital areas: STOs, ATDs, and ACT IIs.

TRADOC annually reviews the current 200 STOs from Army Materiel Command (AMC), Corps of Engineers, Army Medical Research and Materiel Command (MRMC), Army Research Institute for the Behavioral and Social Sciences (ARI), and other Army laboratories for relevance and advancement. Through the battle labs, centers, and schools, TRADOC makes recommendations for continuation of STO efforts and almost as importantly, for removal of or replacement of current STOs. As the list is limited to 200, to add a new effort, one must have been completed or deleted.

The battle labs sponsor the ATDs for the Army. The objective is to evaluate technical performance against specific exit criteria. These S&T funded experiments are conducted in operational, not laboratory, environments over 3 to 5 years. Ideally, experimental results transition into current system improvements or new research and development (R&D) programs.

ACT II gives industry and academia direct access to the battle labs to streamline materiel acquisition and to help provide warfighters with overmatch capabilities. ACT II competitively funds experiments to demonstrate advanced technologies, prototypes, and nondevelopmental items (NDIs) having the greatest potential to fulfill warfighting requirements. Demonstrations are conducted for the battle labs in 12 months or less and are capped at $1.5 million.

3. Advanced Development (6.3)

TRADOC's focus continues in both ATDs and STOs in the 6.3 area. Additionally, TRADOC, through the Deputy Chief of Staff for Combat Development (DCSCD) develops a list of potential ACTDs. These programs, executed at the Office of the Secretary of Defense (OSD) level, are forwarded to the Army's headquarters by the commanding general, TRADOC, for OSD consideration. Although compiled by TRADOC, Army sponsored ACTDs can originate from outside TRADOC—materiel developers, commanders in chief (CINCs), or the joint staff.

Figure II–2 shows TRADOC influence on S&T spending.

		Focused by TRADOC	of	Category Total
Basic Research (6.1)	SROs	$30M		$199M
Applied Research (6.2)	ACT II	$11M		
	ATDs	$15M		$463M
	STOs	$183M		
Advanced Development (6.3)	ATDs	$82M		
	ACTDs	$189M		$418M
	STOs	$58M		
	TOTALS	$568M	of	$1080

TRADOC Focuses 100% of High Priority S&T (STOs/ATDs)
TRADOC Focuses 53% of all S&T

Figure II–2. TRADOC Influence on S&T Spending—FY97

E. TRADOC INNOVATIONS IN SCIENCE AND TECHNOLOGY

During the past 12 months, TRADOC has brought about several innovations to the S&T process. TRADOC's commitment to focusing the S&T dollars is evident by its modifying and developing new processes. These measures are designed to increase the seniority of TRADOC officials approving S&T endeavors. Approval levels for TRADOC S&T actions are:

- SROs/STOs/ACT II: Colonel.
- ATDs: 2-Star General.
- ACTDs: 3-Star General.

1. Advanced Technology Demonstration Review

During 1997, TRADOC for the first time evaluated ongoing and proposed ATDs. ATDs are approved by DCSCD, TRADOC headquarters.

ATDs are a category of Technology Demonstrations (TDs). They are risk-reducing, integrated, proof-of-principle demonstrations designed to assist near-term system developments in satisfying specific operational capability needs. ATDs have been promoted by the Defense Science Board and the Army Science Board as a means of accelerating the introduction of new technologies into operational systems. They are funded principally with 6.3 funds. ATDs facilitate the integration of proposed technologies into full system demonstration and validation (6.4) or engineering and manufacture development (6.5) prototype systems. As such, they provide a link between the technology developer, program manager, program executive officer, combat developer, and the Army user.

Each ATD must meet or exceed exit criteria agreed upon by the warfighter and the ATD manager at program inception (well before the tests begin) and before the technology in question will transition to development. The ATDs seek to demonstrate the potential for enhanced military operational capability or cost effectiveness. Logistics supportability is a consideration during evaluation of ATDs. Active participation by the user and combat developer, as well as by the developer of the technology, is required throughout the demonstration. An ATD consists of multiple subdemonstrations of the item or technology at various locations or as part of various exercises over the 3- to 5-year duration of the ATD. At least one subdemonstration must be conducted at a TRADOC battle lab and an advanced demonstration simulation must also be conducted. Combat developers identify measures of effectiveness/performance applicable to ATD evaluation for applicability and sufficiency for their FOC and warfighting concepts.

Figure II–3 shows the ATD approval process.

2. Advanced Concept and Technology Demonstration Approval by the Commanding General, TRADOC

ACTDs accelerate the application of mature technologies configured in a way that is useful to the warfighter and is in response to a critical military operational need. ACTDs provide an evaluation of the military utility of proposed solutions, and are jointly planned by users and technology developers to enable operational forces to experiment in the field with new technologies in order to evaluate potential changes to doctrine, war-

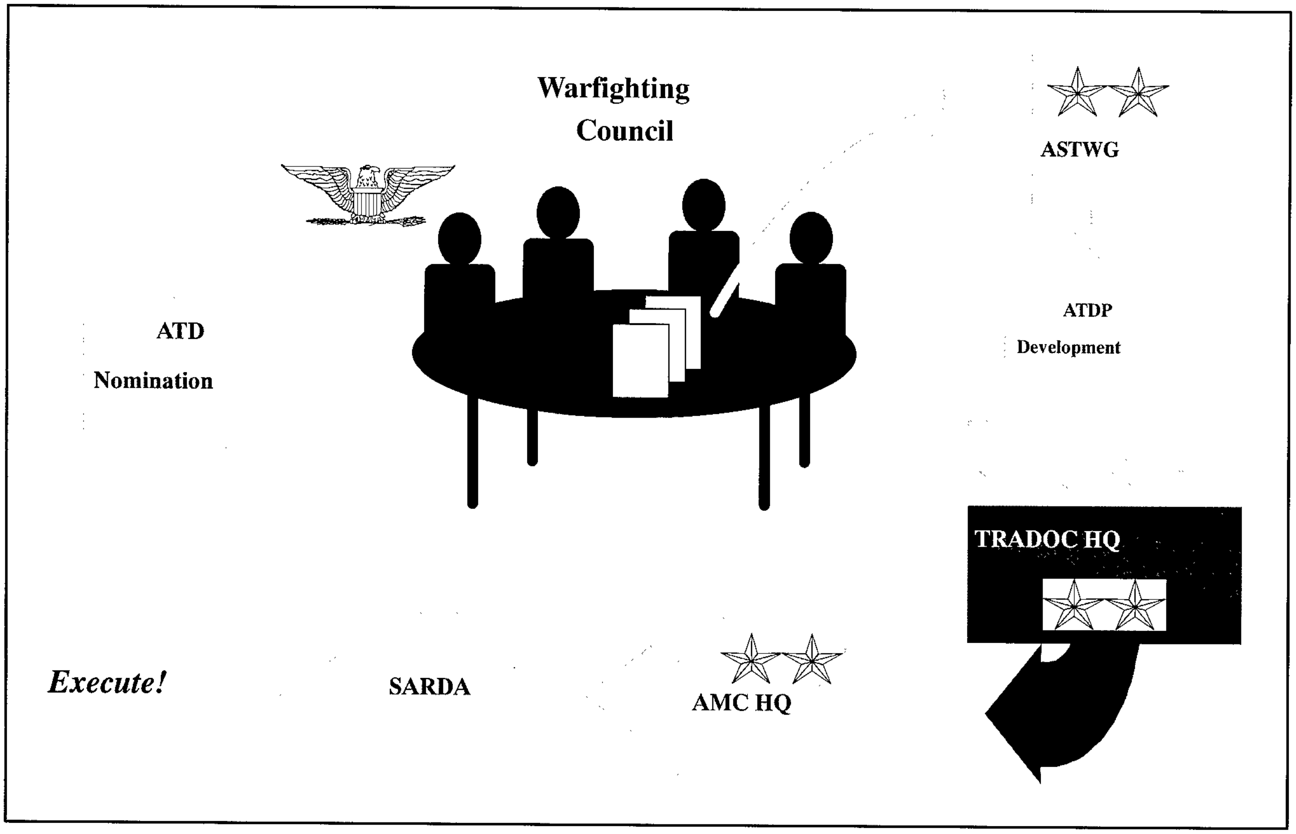


Figure II–3. ATD Approval Process

fighting concepts, tactics, modernization plans, and training. ACTDs are used to develop appropriate concepts of operation, provide insights for the generation or refinement of requirements, and provide residual operational capabilities to the sponsoring user for an extended user evaluation or a contingency operational deployment. Other major goals of ACTDs include promotion of operational jointness, facilitation of senior leadership acquisition decisions, and posturing of ACTD systems for accelerated acquisition, given success and a decision to procure.

TRADOC plays a significant role in the ACTD nomination/approval process. TRADOC provides operational managers for the Army-led ACTDs and requirements integration managers for other services/agencies-led ACTDs. This process is described in detail in T.P. 71–9, Chapter 8–7.

Figure II–4 illustrates the ACTD nomination process.

3. Future Operational Capabilities

FOCs are statements of an operational capability required by the Army to achieve the goals articulated in the hierarchy of concepts (T.P. 525 series) and to maintain military dominance over the operational environment in which it will be required to operate. FOCs are employed in the TRADOC S&T and the STO reviews as measures for assessing the warfighting merits of individual S&T efforts. FOCs guide the Army's S&T investment. Materiel developers and industry use FOCs as references to guide independent research and developments and facilitate horizontal technology integration (HTI). FOCs are used within the *Army Science and Technology Master Plan* (ASTMP) process to provide a warfighting focus to technology based funding.

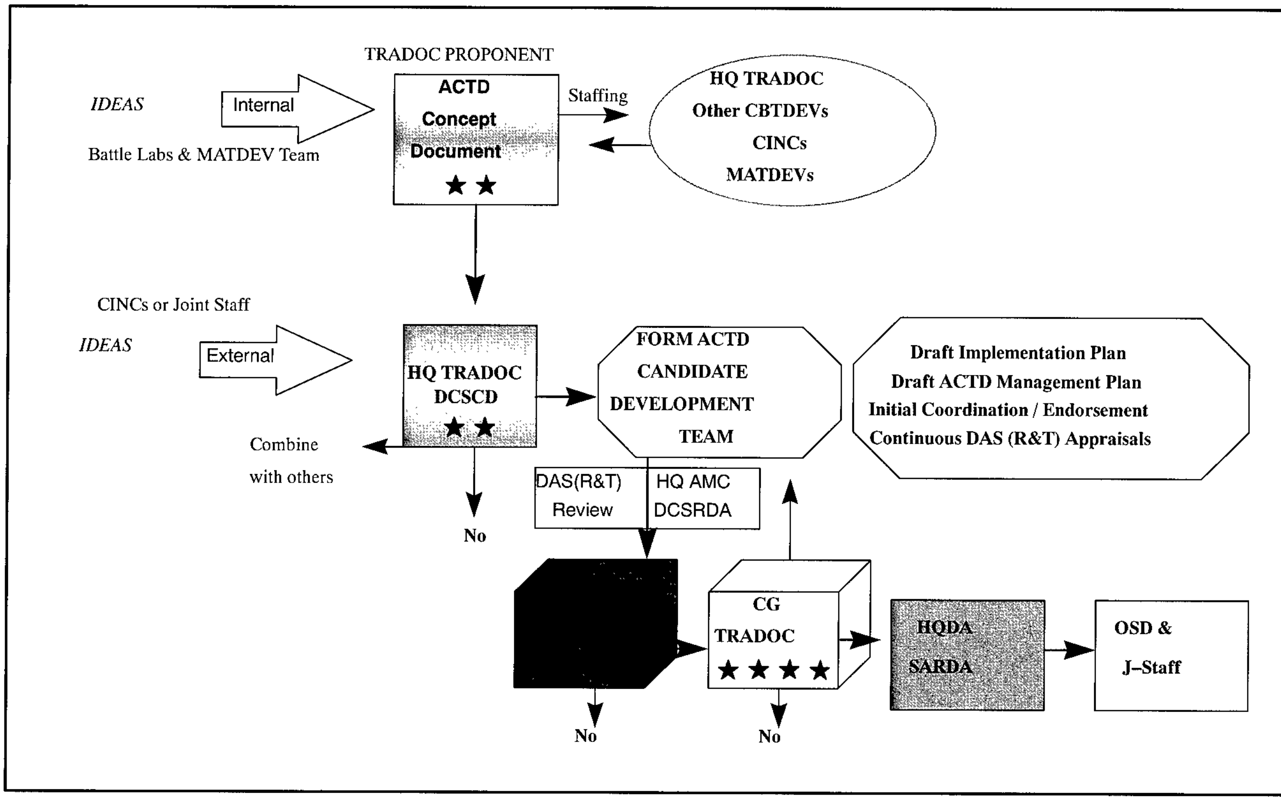


Figure II–4. ACTD Army Nomination Procedure

TRADOC pamphlet 525–66, *Future Operational Capabilities* (see Figure II–5), is the control mechanism for requirements determination activities. It compiles and summarizes the desired future operational capabilities described in TRADOC approved concepts. T.P. 525–66 will be the basis for conducting studies and warfighting experiments.

4. Strategic Research Objectives

To maintain the technological dominance we expect in the future, we must determine today what technologies we need to keep that edge. TRADOC, through the *Army After Next* (AAN), is attempting to determine where we need to look in terms of technologies to explore or exploit in the near term to reach objectives and expectations in the future. A Council of Colonels (COC) conducts a review and makes recommendations to the TRADOC leadership (see Figure II–3, above).

5. *Army After Next* Science and Technology Objectives

Beginning in 1999, an additional category of STOs will be developed (Figure II–6).These STOs will relate directly to advances in the SROs AAN has developed. Each newly nominated STO requires support from a TRADOC director.

6. Battle Laboratory Developments

During 1997, the mission of the battle labs evolved with the implementation of TRADOC Regulation 71–9. This regulation defines the roles and missions of the battle labs and directors of combat developments (DCDs) at the TRADOC centers and schools.

In 1997, three new battle labs were established and one was closed. In June, the Early Entry Lethality and Survivability (EELS) Battle Laboratory was disestablished and its functions transferred to the Combat Service Support Battle Laboratory and Dismounted Battlespace Battle

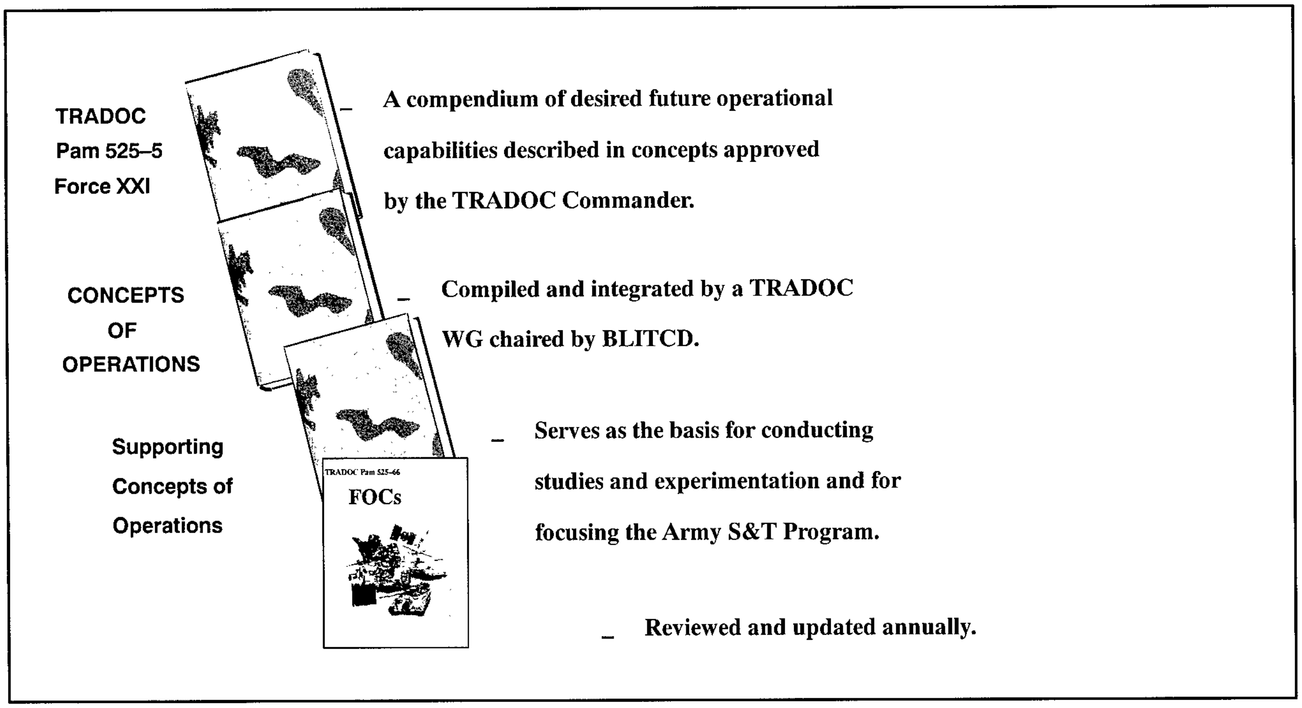


Figure II–5. TRADOC Pamphlet 525–66, Future Operational Capabilities

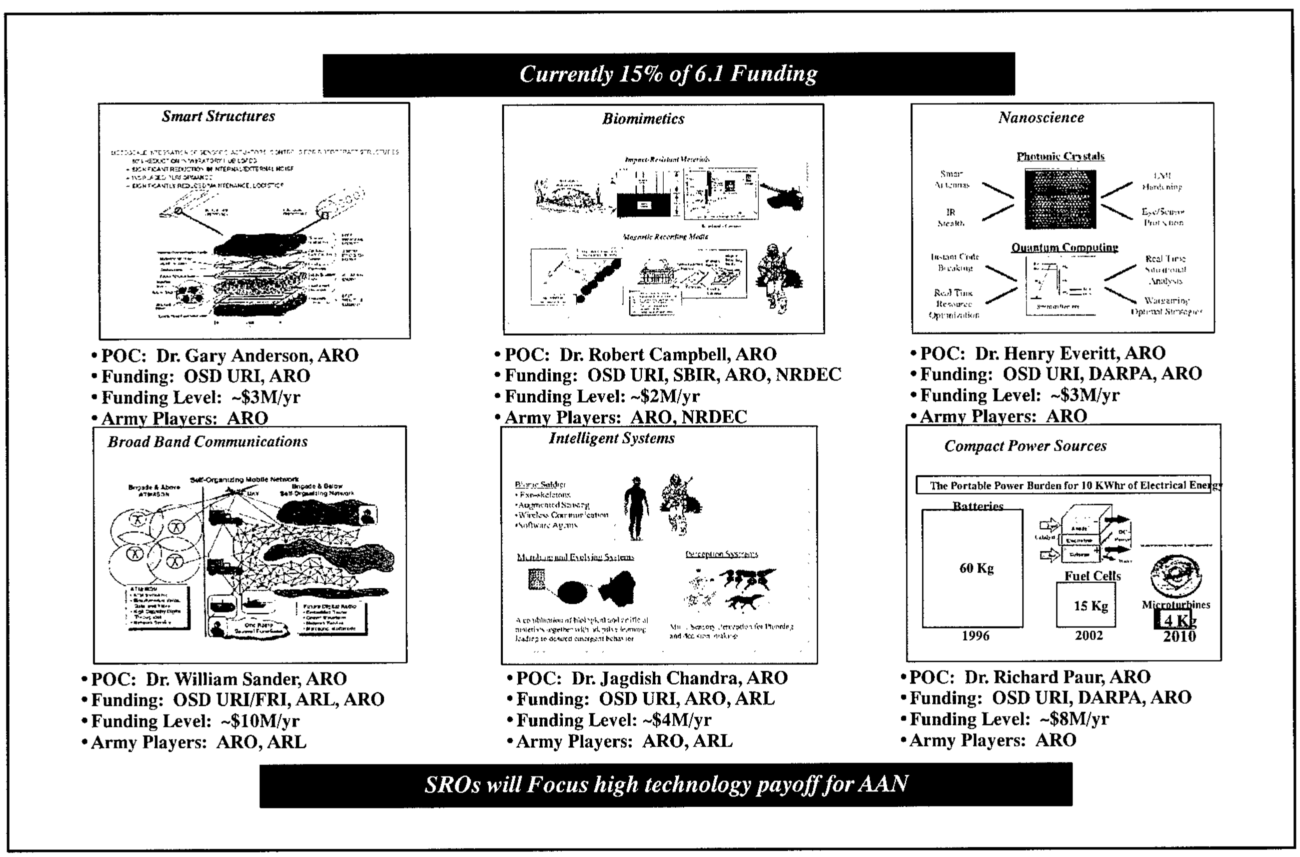


Figure II–6. Validated Strategic Research Objectives

Laboratory. The three new battle laboratories and their corresponding functions are:

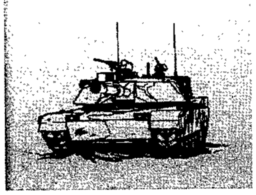
- Maneuver Support Battle Laboratory, Ft. Leonard Wood, Missouri:
  - Examine latest concepts for organization, tactics doctrine, and technological capabilities.
  - Facilitate flow of new ideas and capabilities offered by the strategies of Force XXI.
  - Integrate concepts across the width and depth of the battlefield.
- Air Maneuver Battle Laboratory, Ft. Rucker, Alabama:
  - Provide direction, oversight, and horizontal integration for aviation operations.
  - Improve capability of air maneuver forces to shape the battlespace.
  - Enhance precision strike operations capabilities of the combined arms and joint force.
- Space and Missile Defense Battle Laboratory (SMDBL) Colorado Springs, CO and Huntsville, AL
  - Develop warfighting concepts, focus military S&T research, and experiment to provide space and missile defense DTLOMS capabilities to warfighters
  - Focus efforts on areas beyond the core capabilities of the other battle laboratories.

F. SCIENCE AND TECHNOLOGY REVIEW

TRADOC conducts an annual (December–April) review of all Army 6.1, 6.2, and 6.3 S&T work to give the combat developer an opportunity to review and assess the relevance of the S&T work efforts to the warfighter concepts. It also provides feedback to the materiel developers on the relative merits of each S&T effort. The results from the S&T review will be used by the combat developer to identify potential STO candidates. The review also provides information on perceived shortfalls and redundancies in the Army S&T work efforts (see Figure II–7).

G. SCIENCE AND TECHNOLOGY OBJECTIVES REVIEW

TRADOC serves as the executive agent on behalf of the Deputy Assistant Secretary (Research and Technology) (DAS(R&T)) for the execution of the annual STO review. The STO review provides the forum for the user and developer communities to vote on the warfight-



- Provide input to industry on areas of capability shortfalls and opportunities for investment
- Identify redundancies and shortfalls in the Army S&T program
- Serve as the catalyst for interaction between the combat development community and the materiel development community
- Assess the warfighting relevance of all Army S&T work packages relative to FOCs
- Provide feedback to the director of the S&T agencies on the relative merits of each work package.

Figure II–7. TRADOC Science and Technology Reviews

ing and technical merit of each proposed STO. STO reviews provide the follow-on mechanism to the S&T review that further defines and aligns users' requirements and the materiel developer's efforts. The STO is a necessary link in the S&T cycle (see Figures II–8 and II–9).

H. ADVANCED TECHNOLOGY DEMONSTRATION REVIEW

The STO review provides a basis for ATDs. TRADOC participates in ATDs via battle laboratories and DCDs. TRADOC and the materiel developer (MATDEV) jointly develop a demonstration plan with agreed-upon exit criteria to execute the ATD. ATD management plans are briefed to and recommended by a COC prior to approval at the Army Science and Technology Working Group (ASTWG). ATDs are resource intensive and provide the medium to conduct troop interaction with mature technologies. ATDs have provided significant contributions to the soldiers on the battlefield. The Battle Laboratory Integration, Technology, and Concepts Directorate (BLITCD) serves as the primary coordinator for all ATDs.

I. ADVANCED CONCEPTS AND TECHNOLOGY II PROGRAM

The ACT II program was initiated in 1994 to give industry direct access into the battle labs to streamline materiel acquisition and to help give warfighters overmatch capabilities. ACT II competitively funds industry to demonstrate its advanced technologies, prototypes, and NDIs having the greatest potential to fulfill warfighting requirements. Demonstrations are conducted for the battle laboratories in 12 months or less.

The battle labs develop topics to be solicited via a Broad Agency Announcement (BAA) based on the results of the S&T and STO review processes. These reviews identify gaps and shortfalls in current S&T efforts. Those FOCs lacking Army S&T work are presented as ACT II topics. Those project proposals that can potentially be addressed by industry and best meet the needs of the Army are selected for funding (Figure II–10).

- Army STOs are the top 200 S&T efforts within the Army
- Army STOs are published in the *Army Science and Technology Master Plan* (ASTMP)

BATTLE LABS
MAINTAINING THE EDGE

- Mid January—Materiel Developers (MATDEV) identify completed, revised, and unexecutable STOs
- Mid February—MATDEV nominates candidate STOs
- End of February—Candidate STO fact sheets provided to HQ TRADOC for review
- Mid March—Battle labs provided reclamas on preferred, alternative candidates
- Results briefed to the ASTWG

Figure II–8. Army Science and Technology Objective Review

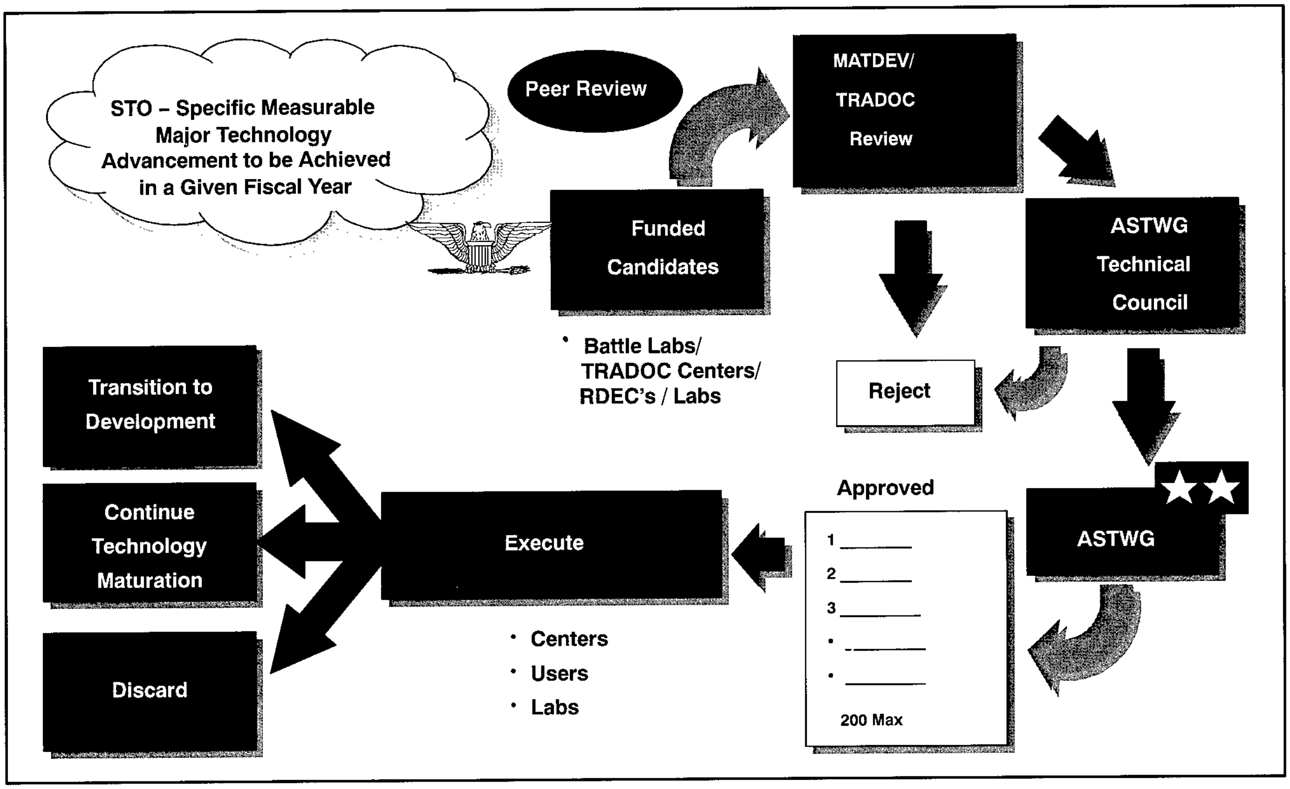


Figure II–9. Science and Technology Objective Process

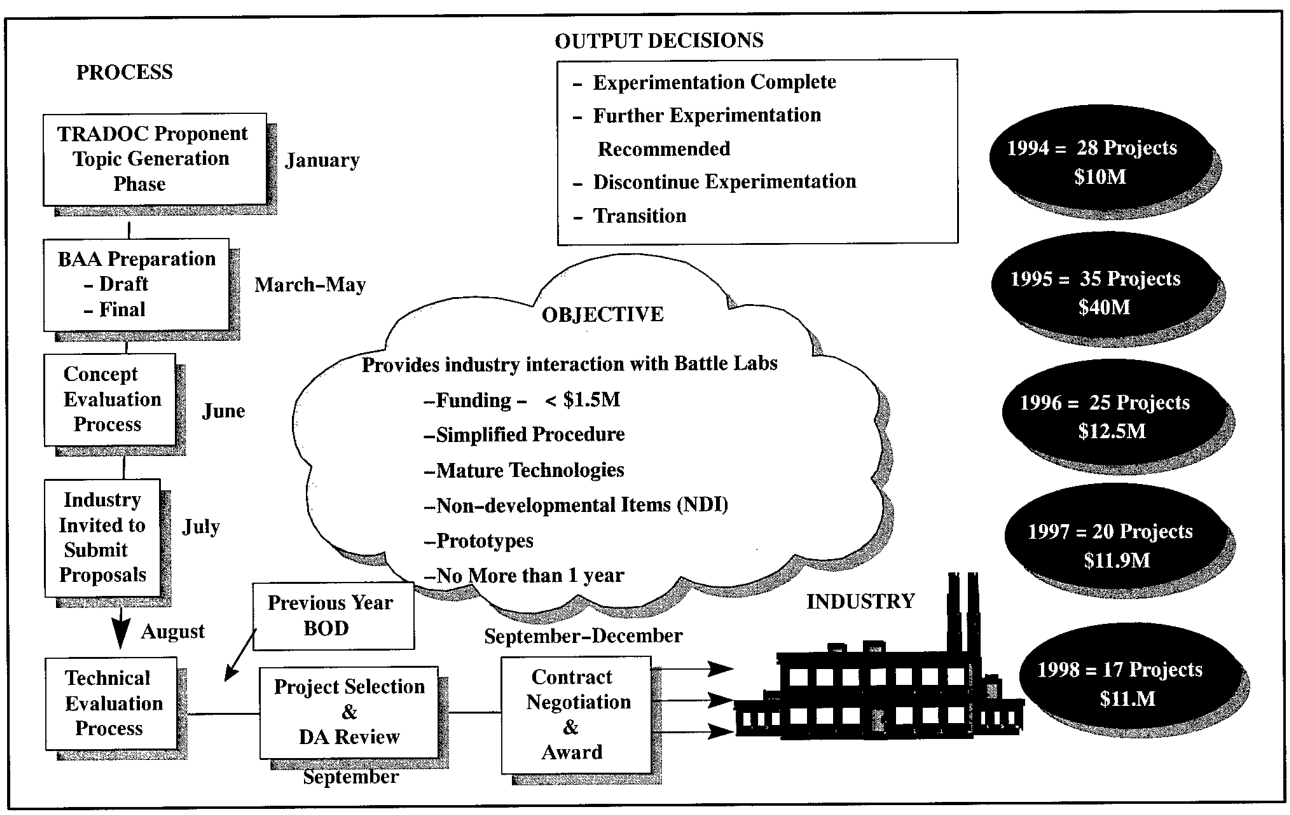


Figure II–10. Advanced Concepts and Technology II Program

J. SUMMARY

These concurrent evaluations of the Army's S&T efforts provide an overlapping assurance that the materiel developers stay focused on the warfighting requirements of the future. They provide a means by which efforts can be validated or refocused, duplication can be eliminated, and gaps can be filled.

K. *ARMY AFTER NEXT* LINKAGE TO THE SCIENCE AND TECHNOLOGY COMMUNITY

The AAN project conducts broad studies of warfare to about the year 2025 to frame issues vital to the development of the Army after about 2010, and provides these issues to the senior Army leadership in a format suitable for integration into TRADOC combat development programs. Studies are currently pursued in four areas focused out to 2025: geopolitics, military art, human and organizational behavior, and technology. The AAN project conducts its studies through an annual cycle of wargames and workshops that culminates in an Annual Report to the Chief of Staff, Army (CSA).

AAN technology insights and issues are developed using networks of technologists from government (DoD and non–DoD), industry, and academia. To ensure that these insights and issues are fed into the S&T investment process and the combat developments process, the AAN project has established close relationships with Office of the Assistant Secretary of the Army (Research, Development and Acquisition), AMC, the Army Research Laboratory, The Army Research Office, and the Defense Advanced Research Projects Agency, as well as the Office of the Deputy Chief of Staff for Operations and Plans and members of the TRADOC combat developments community, to include BLITCD and the battle labs.

While TRADOC's DCSCD presents the commander's position on S&T investments, the AAN project works in concert with the DCSCD to describe the enabling technologies assessed as crucial to the U.S. Army in 2010 to 2025. In particular, the AAN perspective is now sought to determine S&T investments in a certain percentage of 6.1 and early 6.2 programs. In order to carry this out, the AAN project and DCSCD work together in an expanding set of S&T processes. These include the Triennial 6.1 Program Review, the development of Army SROs, and the selection of AAN STOs.

This close working relationship between the AAN project and the DCSCD ensures that the task of handing off technology insights to the combat developments community is a continuous process based on two-way communications. In addition, the challenge of providing continuity from current forces and Army XXI forces to forces in 2025 is met.

The AAN project will support the Army in developing unique partnerships with key members of the S&T community to develop the critical technologies needed for future warfighting. One such player is DARPA, which is already working with the Army to explore innovative concepts and technologies. Other areas of focus include ways to speed up acquisition agility to keep pace with accelerating changes in technology, and innovative business practices that can help to rapidly transform ideas into capabilities (see Figures II–11 and II–12).

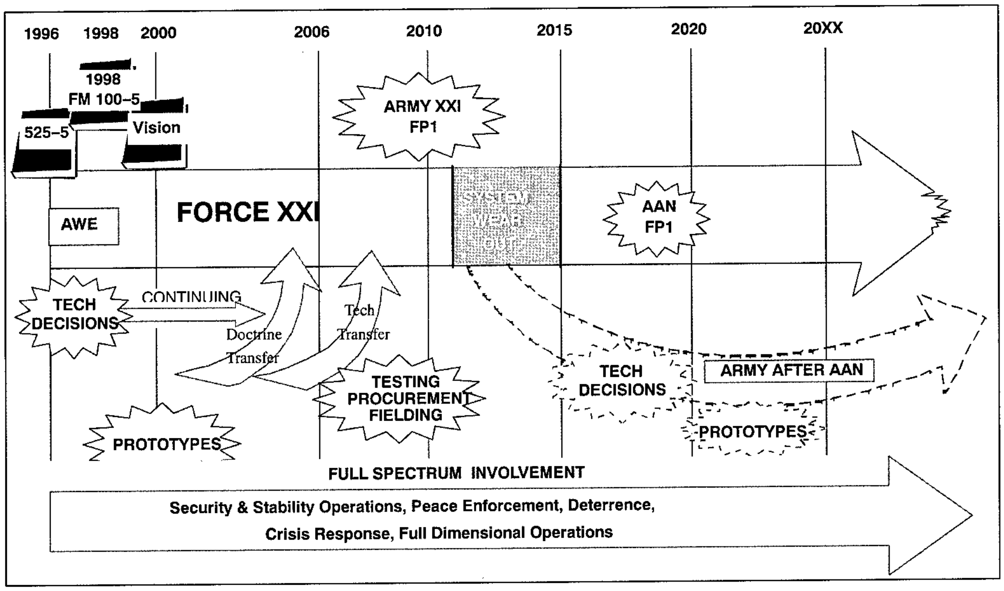


Figure II–11. Influences on the Army's Future—Getting to AAN and Beyond

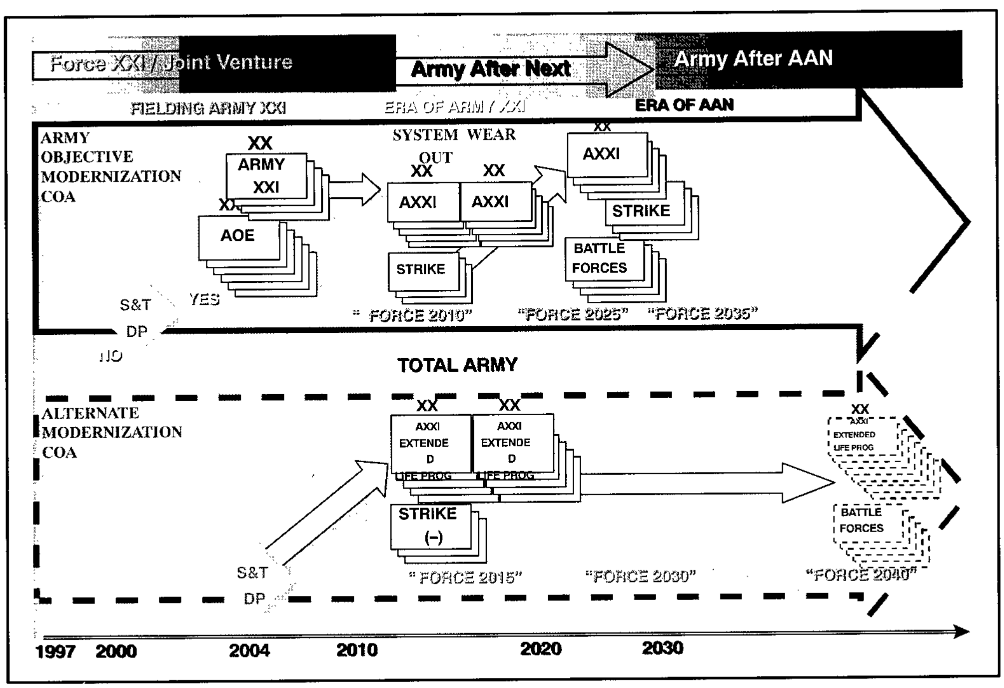


Figure II–12. Army XXI to AAN Decision Points

CHAPTER III

TECHNOLOGY TRANSITION

CONTENTS

CHAPTER III

TECHNOLOGY TRANSITION

We are not the only nation with competence in defense science and technology. To sustain the lead which brought us victory during Desert Storm . . . recognizing that over time other nations will develop comparable capabilities, we must . . . invest in the next generation of defense technologies.

William J. Perry
Former Secretary of Defense

A. INTRODUCTION AND CONSTRAINTS

The ultimate goal of the Army's science and technology (S&T) program is to provide the soldier with a winning edge on the battlefield. The accelerating pace of technological change will continue to offer significant opportunities to enhance the survivability, lethality, deployability, and versatility of Army forces. High-technology research and development is, and will remain, a central feature of the Army's modernization strategy.

The purpose of this chapter is to show the planned transition of promising technology developments into tomorrow's operational capabilities. This transition is accomplished by demonstrations that evolve into the systems and system upgrades incorporated in the *Army Modernization Plan* (AMP).

Because the *Army Science and Technology Master Plan* (ASTMP) is designed to be a funding-constrained document, inclusion of systems/system upgrades and demonstrations in Chapter III was based on their inclusion in the FY99–03 approved Army program objective memorandum (POM), the FY98 defense appropriation, and the FY98 budget estimate submission (BES).

The inclusion of advanced concepts is based on the existence of funded 6.3 technology demonstrations in the POM and in the research, development, and acquisition (RDA) plan, directed toward potential future systems. These advanced concepts represent options that are thought to be technologically achievable and useful on a future battlefield. There is, however, *no firm commitment* by either the Department of the Army or the user community to develop or produce these specific advanced concepts.

Systems and system upgrades contained in this chapter are also included in the approved AMP.

Most of the roadmaps contained in this chapter reflect only limited planned technology demonstration activity beyond the year 2000, due to the ever-changing threat and the difficulty of projecting realistic far-term funding.

B. TECHNOLOGY TRANSITION STRATEGY

1. Technology Transition

The basic strategy of the Army S&T program is to change technology into operational systems to be prepared for future conflict. Because of significant changes in the world security environment over the past several years, the Army is currently focusing on building a smaller, power-projection Army. This "new" Army will capitalize on America's technologies to improve critical areas of development such as protecting the individual soldier and improving battlefield mobility and information management.

Key to this strategy are the Technology Demonstrations (TDs), Advanced Technology Demonstrations (ATDs), and Advanced Concept Technology Demonstrations (ACTDs) that exploit technologies derived from applied research (6.2), which in turn builds on new knowledge derived from basic research (6.1) programs. These TDs, ATDs, and ACTDs provide the basis for new systems, system upgrades, or advanced concepts, which are further out in time. The critical challenge is to tie these programs together in an efficient and effective way.

Technology demonstrations are not new. What is new are the scope and depth of the technology demonstrations, the increased importance of their role in the acquisition process, and the increased emphasis on user involvement to permit an early and meaningful evaluation of overall military capability. The following sections provide an explanation of TDs, ATDs, and ACTDs, as well as systems/system upgrades/advanced concepts (S/SU/ACs).

a. Technology Demonstrations

The primary focus of TDs is to demonstrate the feasibility and practicality of a technology for solving specific military deficiencies. They are incorporated during the various stages of the 6.2 and 6.3 development process and encourage technical competition. They are most often conducted in a nonoperational (laboratory or field) environment. These demonstrations provide information that reduces uncertainties and subsequent engineering costs, while simultaneously providing valuable development and requirements data.

b. Current Advanced Technology Demonstrations

Within each Army mission area, specific ATDs are being structured to meet established goals. Detailed roadmaps to guide their progress are being developed, as well as exit criteria to define their goals. ATDs are risk reducing, integrated, proof-of-principle demonstrations designed to assist near-term system developments in satisfying specific operational capability needs. The ATD approach has been promoted by the Defense Science Board (DSB) and the Army Science Board (ASB) as a means of accelerating the introduction of new technologies into operational systems. They are principally funded with advanced technology development (6.3) funds. ATDs facilitate the integration of proposed technologies into full system demonstration/validation (6.4) or engineering and manufacturing development (6.5) prototype systems. As such, they provide the link between the technology developer, program manager, program executive officer, and the Army user. The criteria for establishing an ATD are:

- Execution at the system or major subsystem level in an operational or simulated operational rather than a laboratory environment.
- Potential for new or enhanced military operational capability or cost effectiveness.
- Duration of 3 to 5 years.
- Transition plan in place for known or potential applications.
- Active participation by the Training and Doctrine Command (TRADOC) battle laboratory and user proponents (see Chapter II).

- Participation by the developer (project manager).
- Use of simulation to assess doctrinal/tactical payoffs.
- Exit criteria established with user interaction/concurrence.
- Consistency with the Army technical architecture.

The Army currently has 20 ATDs that have been approved by the Army Science and Technology Working Group (ASTWG). These ATDs are identified in Table III–1, along with the primary Army mission area each supports. All ATDs are discussed in the applicable Chapter III sections. More detailed information, including exit criteria for each ATD, can be found in Volume II, Annex B. Science and Technology Objectives (STOs) for each ATD are in Volume II, Annex A.

c. Completed Advanced Technology Demonstrations

Four ATDs were successfully completed in FY97. Table III–2 provides details on the results of these ATDs, addressing the product, warfighting capability, and transition of the technology. Additionally, brief descriptions of these ATDs follow.

Table I–1. Correlation Between Ongoing Army ATDs and the *Army Modernization Plan*

ATD	*Army Modernization Plan* Annex Section		ASTMP Description Section	STO
	Primary	Secondary		
Rotorcraft Pilot's Associate	Aviation	IEW	III–D	III.D.01
Battlefield Combat Identification	C^4	IEW, Combat Maneuver, Aviation	III–E	III.E.07
Digital Battlefield Communications	C^4		III–E	III.E.09
Composite Armored Vehicle	Combat Maneuver		III–G	III.G.01
Target Acquisition	Combat Maneuver		III–G	III.G.08
Enhanced Fiber-Optic Guided Missile	Combat Maneuver	IEW	III–H	III.H.03
Precision-Guided Mortar Munition	Combat Maneuver	Fire Support	III–H	III.H.04
Objective Individual Combat Weapon	Combat Maneuver		III–I	III.I.01
Guided Multiple Launch Rocket System	Combat Maneuver		III–N	III.N.11
Vehicular-Mounted Mine Detector	Combat Maneuver		III–M	III.M.08
Direct Fire Lethality	Combat Maneuver		III–G	III.G.10
Integrated Biodetection	NBC		III–K	III.K.03
Multispectral Countermeasures	Aviation		III–D	III.D.13
Air/Land Enhanced Reconnaissance and Targeting	Aviation		III–D	III.D.14
Battlespace Command and Control	C^4		III–E	III.E.06
Future Scout and Cavalry System	Combat Maneuver		III–G	III.G.14
Multifunction Staring Sensor Suite	Combat Maneuver		III–H	III.H.15
Mine Hunter/Killer	Combat Maneuver		III–M	III.M.09
Tactical Command and Control Protect	IEW		III–F	III.F.09
Multimission/Common Modular Unmanned Aerial Vehicle Sensors	IEW		III–F	III.F.06

Table III–2. Completed Advanced Technology Demonstrations

ATD	Product	Warfighting Capability	Transition
Hit Avoidance (III.G.06)	Modeling and simulation (M&S) (Project Guardian) provided cost/affordability and effectiveness data for hit avoidance solutions Near-term active protection system (NTAPS) will defeat horizontal hit-to-kill antitank guided missile (ATGM) threat Enhance distributed interactive simulation (DIS) at Mounted Warfare Test Bed, Ft. Knox, to play hit avoidance technologies CDA universal software module will automate hit avoidance vehicle hardware through fusion of sensors with countermeasures	ATGM defeat improves vehicle and crew survivability Supports digitized battlefield with threat situational awareness Improves tactics, techniques, and procedures of future ground vehicle systems CDA increases hit avoidance system performance Reduces crew workload and stress	CDA to Program Executive Office (PEO)–Ground Combat and Support System (GCSS) (program manager ground systems integration) The suite of survivability enhancement systems (SSES) for fielding on the M2A3 Bradley fighting vehicle
Hunter Sensor Suite (III.H.02)	Two complete hunter sensor suite systems for RFPI demonstration Automatic target recognition software and processor Extended long-range optics Key hunter sensor technologies for future scout and cavalry system	Long-range target acquisition with reduced operator timelines On-the-move operational capability, acoustic 360-degree field of regard for target cueing C^4I automated operator functions Precision targeting hand-off with significantly improved accuracy Reduced signature platform and sensor package Battle damage assessment capability	Key hunter sensor suite technologies to future scout and cavalry system/TRACER program Key technologies and long-range afocal specification for preplanned product improvement (P^3I)—Long-Range Advanced Scout Surveillance System ($LRAS^3$) to PEO–Intelligence and Electronic Warfare (IEW) Two hunter sensor suite systems to RFPI ACTD program manager
Intelligent Minefield (III.M.07)	Gateway (autonomously controls WAMs fires based on user remote strategy selection) IMF simulator prototype for force-on-force modeling and engineering analysis Advanced acoustic sensors	Better operator tactics and control through situational awareness and longer range targeting Improved capability against difficult targets On/off/on and WAM field status for maneuver flexibility/counterattack Capability for commanders to restrict the mobility of the threat, and control battle tempo	Hardware/software technologies transitioned to program manager–mines, countermine demolitions IMF ATD is supporting the RFPI ACTD
Total Distribution (III.O.11)	Logistics anchor desk (LAD) workstations complete with integrated suite of logistics data management tools, decision support tools, and collaborative planning tools Computer M&S techniques Integration to satellite tracking and joint asset databases Network communications management and integration technology	Forms the baseline for logistics planning Enhanced capability to plan, analyze, mobilize, deploy, sustain, and reconstitute material, personnel, and forces in combat and crisis response situations	LAD suite of tools to the program manager combat service support control systems (CSSCS) and Army global command and control system (AGCCS) Joint LAD tools transitioned to GCSS and the Global Command and Control System (GCCS) LAD network management, test, and integration tools to DARPA and NSC LAD deployed to ACOM, EUCOM, and CENTCOM

Hit Avoidance ATD (1995–97). The ATD demonstrated through Battlefield Distributed Simulation (BDS) warfighting experiments improved battlefield effectiveness and developed battlefield tactics for an integrated hit avoidance technology to include sensors, countermeasures, and active defenses against both top attack and horizontal threats. This ATD developed and demonstrated a commander's decision aid (CDA). This is a hardware/software logic module that fuses sensors with countermeasures for automated or aided crewman response. It is a key component of the vehicle protection architecture and can be battlefield tailored to a specific set of threats and used horizontally across multiple combat and tactical vehicles.

Hunter Sensor Suite ATD (1994–97). This ATD has provided major advancements in performance for the Army scout and cavalry systems community. It demonstrated the feasibility of a lightweight, deployable, and survivable hunter vehicle with an advanced long-range sensor suite and reduced signature platform. The sensor suite combined a second-generation thermal imager, day television, eyesafe laser range finder, embedded automatic target recognition (ATR), and image compression/transfer technology for linkage into a C^3 network. Communications data compression techniques/technologies were integrated and demonstrated to permit transmission of imagery over the existing combat net radio systems from the Hunter Sensor platform to the Rapid Force Projection Initiative (RFPI) "standoff killer" weapons in less than 15 seconds. Over current capabilities, the ATD demonstrated an 80 percent reduction in detection times and a 70 percent increase in target recognition range and will allow precision target location to within ≤ 30 meters.

Intelligent Minefield ATD (1993–97). The ATD integrated the wide area munitions (WAMs) with advanced technologies into an autonomous, antiarmor/antivehicle system, and demonstrated improved effectiveness (≥ 50 percent) of individual mines through the use of advanced acoustic sensors, gateway data fusion and coordinated WAM attack. The Intelligent Minefield (IMF) demonstrated the ability for the user to control the WAM fields remotely from the control station through the intelligent gateway based on the sensor information displayed at the control station. Accomplishments included (1) better operator tactics and control—providing the operator with better situational awareness, the capability to track up to seven targets, and individual, real-time target tracks within the WAM field, (2) WAM field performance improvements, and (3) the demonstration of advanced acoustic sensors. Elements of the ATD will also be demonstrated as part of the RFPI ACTD in FY98.

Total Distribution ATD (1994–97). This ATD provided the commanders/logisticians at strategic, operational, and tactical levels an enhanced capability to plan, analyze, mobilize, deploy, sustain, and reconstitute materiel, personnel, and forces in combat or crisis-response situations while reducing logistics timelines and support costs. The ATD demonstrated automated logistics planning tools, computer simulation and modeling techniques, interfaces to advanced microelectronics and satellite tracking, and network communications management and integration technology to support an advanced logistics supply capability. To its credit the ATD successfully participated in Prairie Warrior Exercises '94–'97 and Joint Warrior Interoperability Demonstrations in '95–'97 and provided logistics deployment, sustainment and redeployment planning and operational support to Operation Joint Endeavor, and is deployed to the Atlantic Command (ACOM), the European Command (EUCOM), and Central Command (CENTCOM) as the baseline for the Joint Logistics ACTD. Additionally, the ATD is migrating its log anchor desk (LAD) tools to the combat service support control system (CSSCS) and the Army global command and control system (AGCCS) legacy logistics C^2 systems.

d. Advanced Concept Technology Demonstrations

The ACTD is an integrating effort to assemble and demonstrate a significant, new military capability, based upon maturing advanced technology(s), in a real-time operation at a scale adequate to clearly establish operational utility and system integrity. ACTDs are jointly sponsored and implemented by the operational user and materiel development communities, with approval and oversight guidance from the Deputy Under Secretary of Defense for Advanced Technology (DUSD(AT)).

The ACTD concept is a cornerstone in a procurement strategy that relies on prototyping and demonstration programs to maintain the U.S. military technological edge in the face of declining procurement budgets. ACTDs are a more mature phase of the ATDs. They are 2- to 4-year efforts in which new weapons and technologies are developed, prototyped, and then tested by the soldiers in the field for up to 2 years before being procured. This 2-year residual capability is a unique attribute of an ACTD.

ACTDs are not new programs, but tend to be a combination of previously identified ATDs, TDs, or concepts already begun. They include high-level management and oversight to transform disparate technology development efforts conducted by the various military services into prototype systems that can be tested and eventually fielded. The ACTD becomes the last step in determining whether the military needs and can afford the new technology.

2. Manpower and Personnel Integration Program

The Manpower and Personnel Integration (MANPRINT) program is a comprehensive management and technical program to improve total system (soldier, equipment, and unit) performance by focusing on soldier performance and reliability. This is achieved by the continuous integration of manpower, personnel, training, human engineering, system safety, health hazard, and soldier survivability considerations throughout the materiel life cycle.

Throughout the design and development phases, MANPRINT ensures that an emphasis on soldier considerations is maintained as a high priority in system design and that system operation, deployment/employment, and maintenance requirements are matched with soldier capabilities, training, and availability. The value added of MANPRINT has been demonstrated in programs such as Comanche and Longbow Apache, where application of MANPRINT has led to significant cost avoidance and enhanced mission effectiveness. With MANPRINT, Army systems will become increasingly user-centered, reliable, and maintainable, leading to significant reductions in life-cycle costs and increased mission effectiveness.

3. Army Strategy for Systems, System Upgrades, and Advanced Concepts

a. Systems and System Upgrades

The development of the next set of systems requires prior demonstration of the feasibility of employing new technologies. New systems are those next in line after the ones currently fielded or in production. For these systems, most technical barriers to the new capability have been overcome. Generally, these systems can enter engineering and manufacturing development relatively quickly as a result of the successful demonstration of enabling technologies. Based on current funding guidance, the number of new systems is in a sharp decline. Systems included in this chapter must have a funded 6.4 or 6.5 development program or production dollars in the POM/Army RDA plan.

In the absence of new systems, the Army is pursuing incremental improvements to existing systems to maintain its technological edge and capabilities. For the purposes of this plan, these improvements have been designated as "system upgrades." System upgrades are brought about through technology insertion programs, service

life extension programs, preplanned product improvement (P^3I) programs, and block improvement programs. System upgrades included here must have a 6.4/6.5 funding wedge in the POM/Army RDA plan. These upgrades are based primarily on the success of funded 6.3 ATDs/TDs. The 6.3 ATDs/TDs either are the basis for the system upgrade or have a high probability of forming the basis for the system upgrade. Descriptions of systems and system upgrades may be found in the book *Weapon Systems, United States Army 1997.*

b. Advanced Concepts

Advanced concepts are systems concepts further out in time. For these, significant technical barriers remain, and questions of military worth, including tradeoffs within emerging doctrine and force structure limits, are less clear. Advanced concepts help provide the focus for the earlier stages of technology development (6.1 and 6.2 programs) and outyear projected 6.3 demonstrations. In many cases they are conceptual in nature, and actual system definitions may change significantly by the time technologies and demonstrations are more fully understood. Advanced concepts represent an option that is thought to be technologically achievable and useful on a future battlefield, but without a prior commitment by either the Department of the Army or the user community for development or production. Inclusion of advanced concepts in the ASTMP is based on planned/funded 6.3 ATDs/TDs.

4. Force Modernization Planning

The purpose of an AMP is to formally state the Army's plan for force development and modernization and to clearly articulate specific goals. The AMP is the key planning document in providing long-term continuity within functional areas, while assisting in program prioritization and integration of the total Army force. The AMP is constrained to available structure and programmed resources. It provides the structure and guidance necessary to integrate functional mission area solutions in a constrained resource environment. It is responsive to changing external factors such as emerging capabilities, funding levels, force structure, technology breakthroughs or delays, and the national military strategy. The current functional area annexes to the AMP are listed in the following Section C.

5. Low-Intensity Conflict/Operations Other Than War

Due to the changing world situation, low-intensity conflict (LIC) and operations other than war (OOTW) (e.g., humanitarian assistance, peacekeeping operations, peace enforcement) are becoming increasingly important areas that must be addressed by the development community. This is reflected in the Combat Maneuver Annex (Close Combat Light) to the AMP. New technology is being used to develop systems that support the LIC/OOTW mission. This usually equates in operational terms to equipment being lighter, smaller, more mobile, and less detectable. In each section of this chapter, where appropriate, ties to the Close Combat Light mission area are noted. Additional material is presented in Section III–H.

C. STRUCTURE

This chapter presents the transition of technology into S/SU/ACs in 14 sections corresponding to the Annexes of the FY97 AMP. Because the AMP is uniquely configured, there is not a one-to-one correlation between the Chapter III ASTMP sections and the AMP annexes. The ASTMP sections are as follows:

- Aviation
- Command, Control, Communications, and Computers (C^4)
- Intelligence and Electronic Warfare (IEW)
- Mounted Forces
- Close Combat Light
- Soldier
- Combat Health Support (CHS)
- Nuclear, Biological, and Chemical (NBC)
- Air and Missile Defense
- Engineer and Mine Warfare (EMW)
- Fire Support
- Logistics
- Training
- Space.

Although AMP annexes currently exist for force structure, information mission area, missile defense, and tactical wheeled vehicles, there are no Army S&T-funded technology demonstrations planned. Therefore, there is no corresponding section for these annexes included in Chapter III.

Each section includes a crosswalk, by system, showing the support to the applicable modernization plan annexes. Additionally, each addresses the questions of "why?" and "how?" The "why?" part consists mainly of the discussion of operational capabilities. The "how?" part is addressed in the demonstration descriptions and the roadmaps. Each section is built around the framework displayed in Figure III–1 and contains the following information:

Introduction—A quick synopsis that presents the theme and S&T efforts to be discussed in the section.

Relationship to Operational Capabilities—This section includes a table that ties S/SU/ACs to the applicable Army modernization objectives and

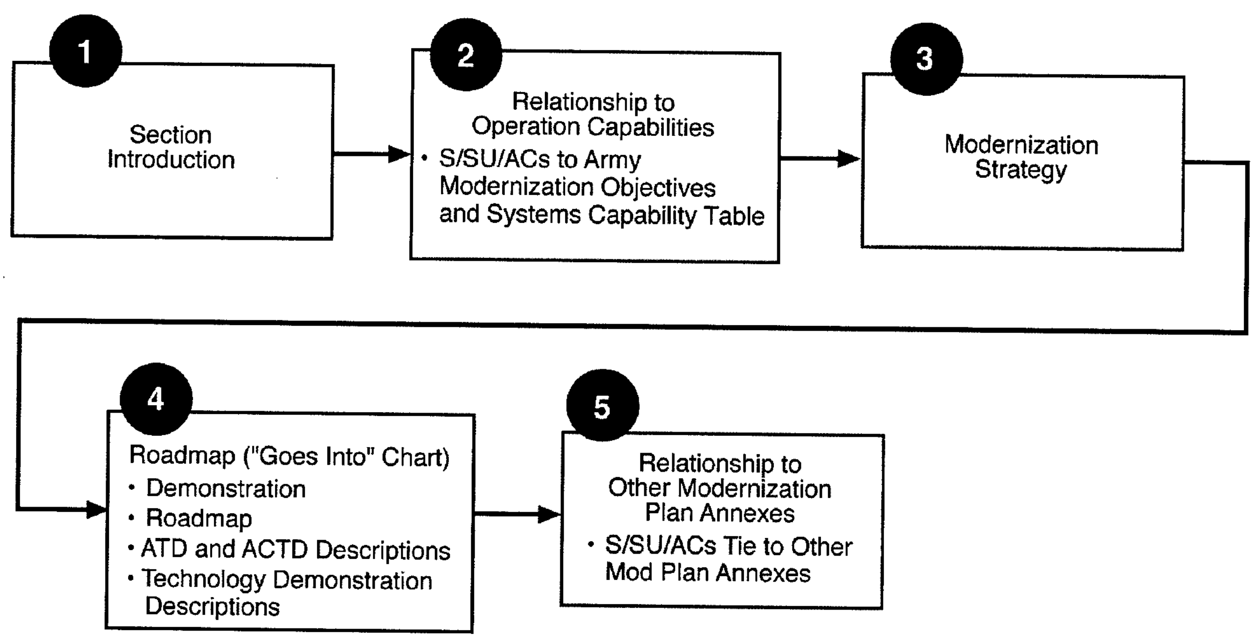


Figure III–1. Framework for Technology Transition Sections

presents the specific new system capabilities required for each area.

Modernization Strategy—A brief synopsis of the applicable modernization strategy.

Roadmap—This is a graphical milestone representation of all the technology transition demonstrations that are covered in the section. It shows approximate timeframes and associated systems for each demonstration. It also captures the evolution to advanced concepts. A summary table presents the systems and demonstrations found in each roadmap.

The roadmap is the heart of each section. The left side of the roadmap lists systems and system upgrades; the demonstrations and tie-ins are shown in the body of the map, and the evolution to advanced concepts is on the right side. (See the C^4 modernization roadmap, Figure III–3, for example.)

Following this, a description of technology demonstrations is provided. This includes a discussion of the technologies being demonstrated in terms of the capability to be provided. Some demonstrations have applications to more than one modernization plan annex. In these cases, the demonstration is described in the primary section and referenced in the other applicable section. Each demonstration description identifies the S/SU/ACs being supported.

Relationship to Other Modernization Plan Annexes—This section presents a matrix displaying systems, system upgrades, or advanced concepts that are supported in, or contribute to, other AMP annexes.

This chapter represents the implementation of the Army's S&T planning process necessary to support the warfighting concepts discussed in Chapter II. It addresses the application of technologies, including emerging technologies, that are discussed in more detail in Chapter IV. Volume II, Annex A, provides the STOs relative to the ATDs and significant technology demonstrations. Descriptive information on the ATDs are in Volume II, Annex B.

In summary, this chapter describes how the Army's S&T program comes together to transfer technology into systems that provide Army operational capabilities.

D. AVIATION

Comanche is the centerpiece of the digital battlefield.

Brigadier General Orlin L. Mullen, USA (Ret.)

1. Introduction

In support of the Army's five strategic modernization objectives, Army aviation showcases the development of the RAH–66 Comanche and AH–64D Apache Longbow helicopters. The armed reconnaissance Comanche will be the centerpiece of the digital battlefield and the Apache Longbow will provide all-weather attack capability. Battlefield commanders will quickly realize the advantages gained through the instantaneous transfer of digital reconnaissance data to the airborne shooters with their three-dimensional (3D) maneuverability/agility to control the ever-changing battlefield tempo. As the threat proliferates and increases, the probability of regional and third-world conflicts and the need for expanded aviation capabilities for deployability, lethality, versatility, and expansibility will continue to be critical.

Consistent with the AMP, the S&T program focuses on projects vital to Army Aviation's fulfillment of its future military role in meeting the emerging requirements of *Joint Vision 2010* and *Army After Next* (AAN). The Army Aviation S&T program will make major contributions to the Army's battle laboratory warfighting capabilities, Force XXI, the nation's rotorcraft industry, and NASA's rotorcraft programs. It is postured to support the development of a joint transport rotorcraft (JTR) that has the potential to fulfill both military and commercial needs. The JTR, as well as other concept studies under investigation, examines the feasibility of using robotic air vehicles for cargo transport and the viability of a multirole/mission adaptable air vehicle, harmonizing joint user requirements for next-generation rotorcraft.

2. Relationship to Operational Capabilities

Force XXI is the Army's near-term effort to modernize and the first step toward meeting the obligations associated with *Joint Vision 2010*. Force XXI focuses on gaining information dominance via digitization of the battlefield, with minimal hardware upgrades in this initial phase of modernization. Army's contribution to *Joint Vision 2010* operational concepts is identified in *Army Vision 2010* as the "land component" of *Joint Vision 2010*. This focuses on the ability of the Army to "conduct prompt and sustained operations on land throughout the entire spectrum of the crisis." It serves as the linchpin between Force XXI and the emerging long-term vision of AAN to "ensure land force dominance across the full spectrum of military operations."

Army aviation acts as a critical element of a joint, combined, or multinational force in future operations with the ability to operate in all dimensions of the battlespace as a dominant force multiplier. Aviation's flexibility and agility is essential for the joint force commander to gain situational awareness, protect the deploying force, and strike the enemy throughout the width and depth of the battlespace.

As a member of the joint team, the Army must compete with a wide variety of programs from other services to reach the goals of *Joint Vision 2010* and AAN. The Army modernization strategy emphasizes highly leveraged R&D, leading-edge technology enhancements, and best use of available resources. This strategy will be used to develop the Army's linkage to *Joint Vision 2010* operational concepts of project and protect the force, shape the battlespace, decisive operations, sustain the force, and gain information dominance.

To meet the varied challenges of the 21st century, Army aviation envisions the family of S/SU/ACs listed in Table III–3. This table presents the correlation between the S/SU/ACs and relevant TRADOC battlefield dynamics. This large, diverse group of dynamics illustrates aviation's ability to support a wide range of combat

Table III–3. Aviation System Capabilities

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
SCOUT/ATTACK							Day/night and adverse weather Integrated cockpit for reduced crew workload Automatic target recognition • Second-generation FLIR • EO/MMW radar • Expert system/processor Antiarmor capability • Laser/RF Hellfire Air-to-air capability • Advanced fire control • Stinger missiles • High rate of fire cannon Area target capability • Hydra–70 rockets Low-cost, precision-kill, 2.75-inch guided rockets (air to ground/ground to ground) Survivability • Signature reduction Advanced flight controls • Fly by wire/light Secure NOE communications data transfer Self deployable Crashworthiness Cockpit air bags	Advanced propulsion Advanced maneuverability/ agility Integrated flight/fire control All-weather nap of the earth (NOE) pilotage Computer-aided low-altitude flight Advanced weapons Automatic target acquisition Mission planning and rehearsal Advanced man–machine integration • Situational awareness • Artificial intelligence (AI)/ cognitive decision aiding Precision navigation Battalion and below command and control operational doctrine status Secure communications–jam resistant Multimodal command understanding NBC sensors and overpressure NBC/directed energy/ballistic protection Survivability/vulnerability Susceptibility–signature control Diagnostics/prognostics/embedded training Fault-tolerant/AI processing Ground maintenance associate Self-deployable Crashworthiness Two-level/paperless maintenance
System								
RAH–66 Comanche	●	●	●	●	●			
System Upgrade								
AH–64D Apache Longbow	●	●	●	●	○			
Advanced Concept								
Enhanced AH–64D Apache	●	●	●	●	○			
Airborne Manned/ Unmanned System Technology	●	●	●	○				
Modular Unmanned Logistics Express			●	●		●		
Multirole Mission-Adaptable Air Vehicle	●	●		●	●	○		

Table III–3. Aviation System Capabilities (continued)

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
CARGO/UTILITY								Range
Advanced Concepts								• Advanced propulsion/ airfoils
Improved Cargo Helicopter	●	●	○	●		●		• Self-deployable
								Lift (advanced transmission)
Joint Transport Rotorcraft	●	●	○	●		●		• Maximize load carrying
								• Minimum noise/vibration
								Cargo handling
								• Increased payload, internal/ external
								• All-weather/day/night, reduced time
								NOE sling load operations
								• Precision navigation/hover
								• Active load stabilization
								Man–machine integration
								• Interactive displays/AI
								Diagnostics/prognostics/ embedded training
								Reduced signatures
								Forward arming and refueling
								Ground maintenance associate

● Provides significant capability ○ Provides some capability

operations. Army aviation is an integral part of all battlefield dynamics. Table III–3 also shows the projected S/SU/ACs capabilities for the aviation functional missions.

Army aviation will continue to be versatile and deployable. It will combine speed, mobility, and firepower in the attack/reconnaissance and assault forces, while moving and sustaining combat power at decisive points on the battlefield with its cargo/utility helicopters. With the evolution of combined arms operations, Army aviation will be even more important in the faster paced battles of the future.

3. Modernization Strategy

The aviation annex to the AMP provides a blueprint for equipping our aviation forces well into the next century with a modern, cost-effective, warfighting fleet able to meet the challenges of low-, mid-, and high-intensity conflicts. The AMP calls for the following major improvements:

- Complete procurement of AH–64D Apache Longbow, complete development and procurement of RAH–66 Comanche, and complete improved cargo helicopter (ICH).

- Support advanced concepts: JTR and Airborne Manned/Unmanned System Technology (AMUST).

Current and future threats to Army aircraft are many and varied. The range of new and emerging technologies available to our adversaries further increases the threat. Many such technologies are intended to improve the effectiveness of air defense systems against low-flying helicopters, while other technologies strive to strengthen the protection of ground systems against attack by air. Undoubtedly, these technologies will become available on the international arms market, resulting in an even more robust capability for our potential adversaries. Our own warfighting concept and modernization requirements are predicated on the need to counter both known and emerging threats.

4. Roadmap for Army Aviation

Table III–4 presents a summary of S/SU/ACs and demonstrations in the Army Aviation S&T program that support the AMP. The roadmap for Aviation (Figure III–2) portrays the Army's use of TDs and ATDs to support the development of its future aviation systems, and dual-use technology for the nation's rotorcraft industry. The Aviation S/SU/ACs are shown at the top of the figure. The lower part of the figure shows the substantial block of Aviation TDs that support the S/SU/ACs and provide the opportunity for technology upgrades of fielded systems. These demonstrations are designed to establish a proof of principle (i.e., to serve as a testbed, validate feasibility, and reduce cost and risk for entering engineering and manufacturing development (EMD)). The roadmap shows two technology insertion windows that offer opportunities for technology application to aircraft S/SU/ACs. Technology insertions that may occur through modification programs for fielded systems, such as AH–64D Apache, UH–60 Blackhawk, CH–47 Chinook, OH–58D Kiowa Warrior, and special operations aircraft (SOA), are not shown.

The following subsections provide descriptions of the aviation demonstrations categorized on the roadmap as mission equipment, advanced platforms, propulsion, and logistics/maintenance.

a. Mission Equipment

Rotorcraft Pilot's Associate (RPA) ATD (1993–99). The primary thrust of the aviation S&T mission equipment area is the RPA ATD. The objective of this program is to establish revolutionary improvements in combat helicopter mission effectiveness through the application of artificial intelligence for cognitive decision aiding and the integration of advanced pilotage sensors, target acquisition, armament and fire control, communications, cockpit controls and displays, navigation, survivability, and flight control technologies. Next-generation mission equipment technologies will be integrated with high-speed data fusion processing and cognitive decision-aiding expert systems to achieve maximum effectiveness and survivability for our combat helicopter forces.

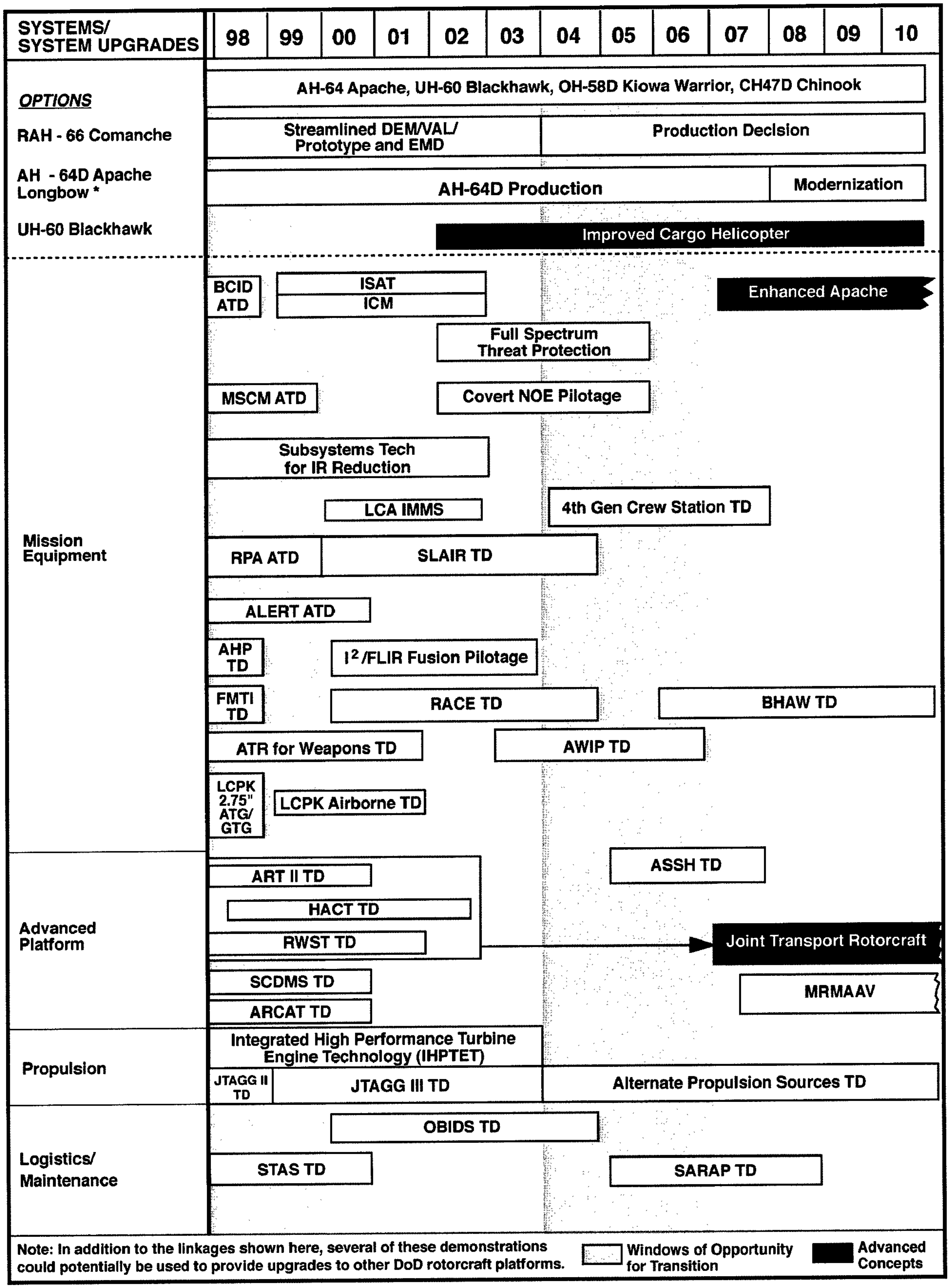
This increased system effectiveness will enable Army aviation to be more responsive to battle commanders at all levels. RPA will expand aviation's freedom of operation, improve response time for quick-reaction and mission redirect events, increase the precision strike capability for high-value/short-dwell-time targets, and increase day/night, all-weather operational capability. RPA will contribute greatly to the pilot's ability to see and assimilate the battlefield in all conditions; to rapidly collect, synthesize, and disseminate battlefield information; and to take immediate and effective actions. These developments will enable the full use of the crew's perceptual, judgmental, and creative skills to capitalize on their own strengths and to exploit the adversary's weaknesses.

The Defense Simulation Internet (DSI), through the Army's Battlefield Distributed Simulation–Developmental (BDS–D) program capabilities, will be utilized in the RPA program to perform measures of performance (MOPs)

Table III–4. Aviation Demonstration and System Summary

Advanced Technology Demonstration	Technology Demonstration
Rotorcraft Pilot's Associate Battlefield Combat Identification (see C^4) Multispectral Countermeasures Air/Land Enhanced Reconnaissance and Targeting	**Mission Equipment** Advanced Helicopter Pilotage Phase I/II Low-Cost Aviator's Imaging Multispectral Modular Sensors Image Intensification/FLIR Fusion Package Survivability/Lethality Advanced Integration in Rotorcraft Autonomous Scout Rotorcraft Testbed Airborne Manned/Unmanned System Technology Low-Cost Precision Kill Low-Cost Precision Kill Guided Flight Low-Cost Precision Kill Airborne Rotorcraft Air Combat Enhancement Brilliant Helicopter Advanced Weapons Full-Spectrum Threat Protection Covert NOE Pilotage System Integrated Sensors and Targeting Integrated Countermeasures Future Missile Technology Integration ATR for Weapons Technology Fourth-Generation Crew Station Subsystems Technology for IR Reductions **Advanced Platforms** Advanced Rotorcraft Aeromechanics Technologies Rotary-Wing Structures Technology Advanced Rotorcraft Transmission Helicopter Active Control Technology Third-Generation Advanced Rotors Demonstration Aircraft Systems Self-Healing Multirole Mission Adaptable Air Vehicle Structural Crash Dynamics Modeling and Simulation **Propulsion** Integrated High-Performance Turbine Engine Technology Joint Turbine Advanced Gas Generator Alternate Propulsion Sources **Logistics/Maintenance** On-Board Integrated Diagnostics Systems Survivable, Affordable, Repairable Airframe Program Subsystems Technology for Affordability and Supportability

System/System Upgrade/Advanced Concept	
System	**Advanced Concept**
RAH–66 Comanche	Survivable Armed Reconnaissance on the Digital Battlefield
System Upgrade	Joint Transport Rotorcraft
AH–64D Apache Longbow Modernization	AMUST
Improved Cargo Helicopter	Modular Unmanned Logistics Express



*System upgrade.

Figure III-2. Roadmap—Aviation

validation. The RPA ATD will achieve the following quantitative MOPs relative to Comanche-like performance during 24-hour, all-weather battlefield conditions: 30 to 60 percent reduction in mission losses, 50 to 150 percent increase in targets destroyed, and 20 to 30 percent reduction in mission timelines. Flight test experiments conducted during the RPA program will provide a measure of simulation validation, evaluate the impact of real-world stimulus, and provide the confidence that technologies are ready to transition into systems, system upgrades, and advanced concepts. *Supports:* Comanche, Apache, SOA, Army Airborne Command and Control System (A^2C^2S), and dual-use potential.

Advanced Helicopter Pilotage (AHP) TD (1994–98). The AHP TD supports the RPA ATD. The AHP TD will develop and demonstrate a night and adverse weather pilotage system to visually couple the aircrew to the terrain flight environment using advanced thermal imaging and image intensifier sensors and a very wide field-of-view, helmet-mounted display. The AHP display system will provide current and future Army aircraft with increased safety and situational awareness, reduced pilot cognitive workload, increased mission launch rates, and enhanced terrain flight operations. *Supports:* RPA, Comanche, Apache, and SOA.

Battlefield Combat Identification (BCID) ATD (1993–98). The BCID ATD will demonstrate target ID techniques together with situational awareness information that will minimize fratricide during ground-to-ground and air-to-ground engagements. It is discussed in detail in Section III–E, "Command, Control, Communications, and Computers." *Supports:* Scout and Attack Aircraft, ACT/JTR, and ICH.

Multispectral Countermeasures (MSCM) ATD (1997–99). The purpose of the MSCM ATD is to develop prototype hardware for an advanced technology, low-cost coherent jammer to protect Army helicopters from imaging infrared surface-to-air missiles. The integration of a missile detector, a high-accuracy point/track subsystem, and an IR laser with fiber optic coupling and advanced expendables will be demonstrated. A multiline or wavelength-agile source will be used to improve its effectiveness against missiles with counter-countermeasures and to develop a capability against IR imaging seekers. *Supports:* All fielded aircraft and ICH.

Integrated Sensors and Targeting (ISAT) TD (1999–02). This program will develop a leap-ahead targeting upgrade to the suite of integrated RF countermeasures (AN/ALQ–211) and suite of integrated IR countermeasures (AN/ALQ–212). Apache Longbow AH–64D aircraft will have precision geolocation and targeting of emitters on the battlefield. Using its integrated variable message format (VMF) interface to on-board communications systems, Apache Longbow will be capable of providing friend or foe classification of radar emitters on the battlefield. *Supports:* Upgrades to the AN/ALQ–211 and AN/ALQ–212, AH–64D Apache Longbow, Integrated Countermeasures, and common air/ground electronic combat suite (CAGES).

Integrated Countermeasures (ICM) TD (1999–02). This program will develop and demonstrate a leap-ahead integrated RF, EO, IR countermeasures system upgrade for the AN/ALQ–211 and AN/ALQ–212 systems for both conventional and reduced signature aircraft with horizontal technology integration (HTI)-to-ground survivability. This program will counter such future threats as multispectral RF, IR missile seekers, and air defense systems using integrated radar, laser, and FLIR target acquisition and tracking, to include special reduced detection jamming nodes for reduced signature platforms. This integrated approach will permit a multispectral countermeasures attack on enemy weapon systems during their acquisition, tracking and homing phases, to include jamming of proximity fusing. *Supports:* Upgrades to the AN/ALQ–211 and AN/ALQ–212, Integrated Countermeasures, and CAGES.

Air/Land Enhanced Reconnaissance and Targeting (ALERT) ATD (1997–00). This ATD will demonstrate automatic target acquisition

and enhanced target identification via a second-generation FLIR/multifunction laser sensor suite for rapid wide area surveillance and targeting. ALERT will leverage ongoing Air Force and DARPA developments for search on-the-move ATR. Second-generation FLIR and multifunction laser data will be fused to allow large search areas to be covered with high targeting accuracy while at low depression angles and high platform motion. Range profiling of the highest priority targets will provide target identification. *Supports:* Comanche and Apache Improvements.

Low-Cost Aviator's Imaging Multispectral Modular Sensors TD (2000–02). This effort will develop and demonstrate multispectral pilotage sensors that leverage state-of-the-art technologies for sensors and displays, including FLIR, image intensifier, obstacle detection sensors, and wide field-of-view (40 × 90 degrees) optics. The program will develop a core suite of modules with high-resolution performance and low-light-level capabilities required for pilotage sensors to achieve HTI across the aviation fleet to include attack, reconnaissance, utility, and cargo aircraft. The approach will improve aviators' safety-of-flight, situational awareness, and pilotage capabilities under night battlefield, adverse weather, and military operations in urban terrain (MOUT) conditions. *Supports:* Attack, Reconnaissance, Utility/Cargo Aircraft, Air Warrior, and Mounted Battlespace.

Image Intensification (I^2)/FLIR Fusion Pilotage TD (2000–03). This TD will demonstrate image fusion upgrades to the baseline Comanche dual-spectrum (I^2/IR) pilotage system to increase mission effectiveness and survivability for future high-performance rotorcraft. Knowledge-based image fusion algorithms will significantly enhance image resolution and will support concurrent demonstration of aided NOE pilotage technology. *Supports:* Future Comanche/Apache Upgrades.

Future Missile Technology Integration (FMTI) TD (1994–98). The FMTI TD will demonstrate the integration on the Bradley fighting vehicle of a lightweight, fire-and-forget, multirole missile system for air-to-air and air-to-ground engagements. It includes the integration of command guidance, control, propulsion, airframe, and warhead technologies capable of performing in high-clutter/obscurants, adverse-weather environments and under countermeasure conditions. Missile flight control and guidance system technology will explore capabilities such as lock-on-before/lock-on-after launch, fire-and-forget, command guidance, signal and image processing, and secure wideband data links. Demonstrated missile system performance (i.e., weight, range, kill ratio, speed, and lethality) will be optimized to exceed current baseline parameters of air-to-ground Hellfire and ground-to-ground tube-launched, optically tracked, and wire command-link guided TOW. *Supports:* HWMV, M2 Bradley, Follow-On to TOW (FOTT), Hellfire III, RAH–66 Comanche, and AH–64 Enhanced Apache.

Survivability/Lethality Advanced Integration in Rotorcraft (SLAIR) TD (2000–04). The SLAIR TD will integrate, simulate, and flight demonstrate the next-generation mission equipment technologies necessary for attack and scout helicopters to fight effectively and survive in Force XXI. Candidate technologies under development by many research, development, and engineering centers (RDECs) include advanced weapon technology (lethal and nonlethal), ATR/combat identification, advanced fire control, survivability, C^3, and the next generation of cognitive decision aiding beyond the RPA. The SLAIR TD will synergistically demonstrate the capabilities of combat versatility, tailorable kill levels, reduced engagement timelines, increased survivability, and reduced fratricide. *Supports:* AH–64D Apache Longbow Modernization, RAH–66 Comanche, potential improvement to Marine AH–1W Super Cobra, and dual-use potential (nonlethal).

Low-Cost Precision Kill (LCPK) Concept TD (1996–98). This effort will demonstrate, through hardware-in-the-loop (HITL) simulation, at least two approaches to a low-cost, stand-

off range, precision guidance and control retrofit package for the 2.75-inch rocket. In current operations, large numbers of unguided 2.75-inch rockets would be required to achieve high probability of kill against point and nonheavy targets at standoff ranges, resulting in unacceptable collateral damage and creating a significant logistics burden. With the addition of a retrofit guidance and control package, accuracy comparable to current guided munitions can be obtained. This greatly improved accuracy will reduce the number of rockets required to defeat nonheavy armor point targets by up to two orders of magnitude, thereby providing a 4:1 increase in stowed kills at one third the cost compared to current guided missiles. *Supports:* AH–64 Apache, OH–58D Kiowa Warrior, Hydra–70 Improvement, and Special Operations Forces (SOF).

ATR for Weapons TD (1998–01). Conventional weapon systems seek to extend their range through various technology approaches to facilitate a more favorable loss-exchange ratio on the battlefield. Coupled with this extended range is a requirement or a stated need for fire-and-forget conventional weapon systems. This technology demonstration will explore the missile-based weapon systems' autonomous target recognition through the use of passive moving target indication (MTI), rapidly retrainable pattern recognition algorithms, and techniques for rapid downloading from the platform to the weapon. Comparison of synthetic discriminant function (SDF) performance capability with other techniques, such as those already in use with laser radar (LADAR) data, and the quantifying of the computing requirements for all the algorithms to determine what is most appropriate for the close combat scenario will be demonstrated using realistic battlefield environments to include, for example, smoke and countermeasures. ATR has the potential to provide the soldier with a weapon that has true lock-on-after-launch (LOAL) fire-and-forget capability at extended ranges with the added benefits of reacquisition of targets after loss of lock, friendly avoidance, and optimum aimpoint selection for increased warhead effectiveness. *Supports:* Hellfire III, Brilliant Antitank (BAT) P^{3}I, Multiple Launch Rocket System (MLRS) Smart Tactical Rocket (MSTAR), Enhanced Fiber Optic Guided Missile (EFOGM), Unmanned Aerial Vehicle (UAV), and extended range fire-and-forget that demands LOAL, Unmanned Ground Vehicle (UGV), Avenger, FOTT P^{3}I, Javelin, Stinger, and Future Missile Technology Integration (FMTI).

LCPK Guided Flight TD (1999–00). This program will demonstrate, through ground-launched guided flight tests, at least two approaches to a low-cost, standoff range, precision guidance, and control retrofit package for the 2.75-inch rocket. LCPK risk reduction technologies and approaches, including strapdown semiactive laser (SAL) and Scatterider seekers, guidance section decoupling from rolling rocket motor, two-axis canard controls, and small low-cost inertial devices will be evaluated. *Supports:* AH–64D Apache, RAH–66 Comanche, Kiowa Warrior OH–58D, SOF, Hydra–70 Improvement Program, and potentially Navy/Marine Corps AH–1W.

LCPK Airborne TD (1900–01). This effort will flight demonstrate the helicopter integration of the best 2.75-inch guided rocket system obtained from the LCPK Guided Flight TD. The LCPK system will be evaluated from a helicopter system perspective to ensure aircraft compatibility and performance effectiveness. *Supports:* AH–64D Apache, RAH–66 Comanche, Kiowa Warrior OH–58D, SOF, Hydra–70 Improvement Program, and potentially Navy/Marine Corps AH–1W.

Brilliant Helicopter Advanced Weapons (BHAW) TD (1906–10). The BHAW TD will integrate and demonstrate, through simulation and ground/flight test, future combined arms interoperable advanced aviation weapons, target acquisition and fire control technologies, and aviation platforms and will quantify resulting increases in aviation mission effectiveness. Full spectrum lethality will be demonstrated from "less than lethal" tailorable up to conventional

lethal kill mechanisms. Technology candidates for the BHAW TD include:

- Low-cost precision kill weapons with low collateral damage, including brilliant missile technology with immunity to countermeasures.
- Innovative less than lethal kill mechanisms, such as directed-energy techniques, that immobilize or disrupt personnel, vehicles, or other equipment.
- Advanced auto cannon technologies (e.g., cased-telescoped, bursting munitions, electrochemical and electromagnetic propulsion, electrostatic proximity fuses, closed-loop fire control).
- Automatic target acquisition, recognition, and covert identification that uses multidata/sensor fusion of advanced on- and off-board distributed target acquisition concepts.
- Intelligent fire and flight control, 360-degree aircraft aspect that provides quick reaction precision kill with tailorable lethality level and selectable automatic engagement feature.

Supports: Comanche and Apache.

Rotorcraft Air Combat Enhancement (RACE) TD (2000–04). The probability is increasing that Army helicopters will encounter airborne threats in future conflicts. There is a need to develop an air-to-air capability for Army aviation to defeat the threat and protect itself and friendly forces. The RACE TD will develop, integrate, and airborne demonstrate the technologies necessary for the Army's existing and future helicopters to meet the need. Technology candidates include improvements to gun, rockets/missiles, target acquisition and fire control systems, and other aircraft system technology necessary to achieve an air-to-air system solution. *Supports:* AH–64D Apache Longbow Modernization and RAH–66 Comanche.

Full-Spectrum Threat Protection TD (2002–05). This TD demonstrates balanced integration of rotorcraft survivability for the most effective combinations of active countermeasures and susceptibility reduction features for full spectrum threats (i.e., radar, acoustics, IR, and visual). It will demonstrate survivability against advanced threat sensors and smart weapons and munitions. The survivability codes will be validated and verified by installing equipment on aircraft with known signature and flight testing against various threats. Enhanced survivability and system performance features for aircraft, to include S/SU/ACs and UAVs, will be tailored for specific warfighting situations by minimizing weight and aerodynamic impact while maintaining low-observable cross section, minimizing threat detection of active countermeasures, increasing jammer effectiveness, optimizing mission routes and tactics, and reducing production costs. *Supports:* TRADOC battle labs, Force XXI, Project Reliance, and multiservice applications.

Covert Nap-of-the-Earth (NOE) Pilotage System TD (2002–05). This TD will demonstrate an advanced, effective, and highly integrated rotorcraft pilotage system to operate covertly NOE and unobtrusively in urban areas with increased survival in hazardous flight environments or emergency situations with reduced crew workload during day, night, and adverse weather. Reduced crew workload, aided precision flightpath control, and increased safety will enable crew members to focus on mission-level functions while maintaining full vehicle and flightpath control. The TD will demonstrate a comprehensive air vehicle management system for pilotage; a large-scale integrated mission equipment suite; automated protection from obstacles, terrain, and other in-flight hazards; an increased capability for rotorcraft operations avoiding and using obstacles, terrain, and threats for military operations; and increased safety for military and commercial rotorcraft operating in hazardous flight environments. *Supports:* JTR, ICH, Enhanced Apache, and far-term manned and unmanned rotorcraft.

Fourth-Generation Crew Station TD (2004–07). This TD will demonstrate the next gen-

eration of air vehicle crew station architecture. The effort will develop and incorporate advanced displays for full glass cockpit/crew station; 3D display technology; selectable touch, cyclic grip cursor, or pupil-tracked cursor information access capability; rapid pilot-reconfigurable information layout on displays; automated AI "advisor" aiding; intelligent, adaptive interfaces; advanced selectable "windowless" cockpit synthetic vision systems; advanced information display symbology, and advanced flight control designs. Displays, AI, and crew station technology from Air Force, Navy, and NASA programs will be incorporated into system design. The TD will demonstrate increased pilot performance and overall mission and reduced pilot susceptibility to injury by laser, directed energy, or other sources in hostile electromagnetic environments. *Supports:* JTR, ICH, Enhanced Apache, MRMAAV, and advanced ground vehicle crew stations.

Subsystems Technology for Infrared Reductions (STIRR) TD (1997–01). The focus of STIRR is IR technology development, integration, and demonstration to improve the survivability of Army rotary-wing vehicles. The primary goal of increased survivability will be addressed via aggressive efforts to reduce synergistically the thermal emissions from helicopter airframes while developing and improving systems designed to cool plume and engine heat signatures. STIRR will achieve development of advanced, multispectral (visual through far IR) airframe coatings that are compatible with radar absorbing materials/structures and development of state-of-the-art, low-cost, lightweight thermal insulative materials. STIRR will support validation of advanced computational aero/thermo modeling and simulation (M&S) tools that will be used to develop innovative engine IR suppression techniques. Additional quantifiable payoffs of passive signature reduction are direct improvements in active countermeasures performance through increased jamming/signal (J/S) ratios and improved decoy effectiveness. *Supports:* Current and future rotary-wing system upgrades, JTR, Comanche, USAF, USN, and USMC vertical lift air vehicles, AH–64D, UH–60, RAH–66 upgrades, ICH, and other services' fleets.

b. Advanced Platforms

Advanced Rotorcraft Transmission (ART) II TD (1997–00). The ART TD incorporates key emerging material and component technologies for advanced rotorcraft transmissions and makes a quantum jump in the state of the art. The ART–II TD will survey the applicable ART–I (completed in FY92) component technologies and proposed concepts and will integrate the more promising ones into selected transmission/drive subsystem demonstrators. Advanced concepts such as split torque, split path, and single planetary transmissions will be considered with advanced material applications/component designs to demonstrate lighter, quieter, threat-tolerant, more durable, reliable, and efficient drivetrain subsystems. *Supports:* JTR, ICH, Apache, and dual-use potential.

Helicopter Active Control Technology (HACT) TD (1998–02). The HACT TD will demonstrate a second-generation fly-by-light control system technology and integration of flight control and mission functions into a vehicle management system (VMS). Advanced processing for fault-tolerant systems, individual blade/higher harmonic control, and smart actuation concepts will be considered. It will demonstrate high-bandwidth active control technologies, multimode stabilization, and carefree maneuvering and robust control law design methodologies for affordable high-performance helicopter control systems.

The HACT will provide enhanced night/adverse weather mission effectiveness during confined or terminal area operations capability, reduced workload, and improved crew endurance. It will maximize ability of the flight crew to exploit inherent vehicle performance, maintain safety and reliability while improving affordability and operations and support (O&S) costs, simplify maintenance, and reduce fleet attrition. *Supports:* Comanche, Apache, JTR, and ICH.

Third-Generation Advanced Rotor Demonstration (3rd GARD) TD (2001–04). The 3rd GARD TD will demonstrate advanced rotors and rotor concepts to enhance current performance ceilings through high lift airfoils/devices, tailored platforms and tip shapes, elastic/dynamic tailoring methods, active on-blade control methods, acoustic signature reduction techniques, and integration of advanced rotors and rotor concepts with advanced active control systems. 3rd GARD technology will provide for increased survivability via reduced acoustic signature and increased maneuverability/agility, increased rotorcraft speed capability, increased range and payload, and reduced O&S cost via reduced vibration and loads. *Supports:* Far-term advanced rotorcraft concepts.

Aircraft System Self-Healing (ASSH) TD (2005–07). The ASSH TD will demonstrate a self-healing flight control system for rotorcraft that automatically reconfigures remaining air vehicle lift, control, and applicable mission equipment assets to compensate for the degradation of vehicle control when caused by battle, obstacle strike, or premature subsystem or component failure, and will advise the crew for appropriate action. The TD will demonstrate robust fault detection and identification of critical failures through onboard expert system diagnostics, compensation strategies for damaged aircraft subsystems, and smart flight control component technology. ASSH technology improves the survivability of crew and aircraft by providing a return-home capability for damaged aircraft, reduced aircraft losses, increased operational flexibility, productivity during all mission phases, and mobility of damaged assets. *Supports*: Far-term advanced concepts.

Multirole Mission Adaptable Air Vehicle (MRMAAV) TD (2008–11). The MRMAAV TD will demonstrate the feasibility of using a common airframe and powerplant(s) to conduct multiple primary mission roles with the same aircraft with minimal impact on equipment interchanges (e.g., avionics, weapons, survivability packages). Common dynamics and aeromechanics components would be incorporated to support development of manned and unmanned systems. The MRMAAV concept offers battlefield commanders unprecedented mission flexibility to reconfigure aircraft in the field for various mission roles. Fewer numbers of aircraft and crews will be required to perform multiple missions. *Supports:* Far-term advanced concepts.

Structural Crash Dynamics Modeling and Simulation (SCDMS) TD (1997–00). SCDMS will establish a structural crash dynamics M&S capability from a single selected off-the-shelf computer code that can satisfy the need for a design and performance evaluation tool to be optimized for helicopter crashworthy systems or materials, and for scenarios common to helicopter crashes. A uniform standard approach to computer modeling of global helicopter crash dynamics will be established. SCDMS will utilize the Army Research Laboratory (ARL), the Virtual Simulation Directorate, and NASA Langley Research Center modeling and testing expertise in support of the four-phase effort, evaluating state-of-the-art M&S codes to determine strengths and weaknesses and to select code with the most strengths. *Supports:* ICH.

Rotary-Wing Structures Technology (RWST) TD (1997–01). RWST will fabricate and demonstrate advanced lightweight, tailorable structures, and ballistically tolerant airframe configurations that incorporate state-of-the-art computer design and analysis techniques, improved test methods, and affordable fabrication processes. The technology objectives are to increase structural efficiency by 15 percent, improve structural loads prediction accuracy up to 75 percent, and reduce costs by 25 percent without adversely impacting airframe signature. *Supports:* Battle laboratories, JTR, ICH, UH–60 upgrades, and collaborative technology.

Advanced Rotorcraft Aeromechanics Technologies (ARCAT) TD (1997–00). ARCAT will develop and demonstrate critical technologies in rotorcraft aeromechanics to contribute to enhanced warfighting needs for fielded and next-generation systems. Research and development

will be conducted to achieve technical objectives by increasing maximum blade loading, increasing rotor aerodynamic efficiency, reducing adverse forces, reducing aircraft loads and vibration loads, reducing acoustic radiation, increasing inherent rotor lag damping, and increasing rotorcraft aeromechanics predictive effectiveness. Achievement of aeromechanics technology objectives will contribute to rotorcraft system payoffs in range, payload, cruise speed, maneuverability/agility, reliability, maintainability and reduced research, development, test, and engineering (RDT&E), procurement, and O&S costs. *Supports:* Battle labs and Force XXI.

c. Propulsion

Integrated High-Performance Turbine Engine Technology (IHPTET) Program [Joint Turbine Advanced Gas Generator (JTAGG)] TD (1991–03). JTAGG is a tri-service effort that is structured to be compatible with the goals of the IHPTET initiative. IHPTET is a three-phase tri-service/DARPA/NASA effort with major milestones in 1991, 1997, and 2003. The JTAGG I+ was completed in 1994. Specific JTAGG I+ goals included a 25 percent reduction in fuel consumption and a 60 percent increase in power-to-weight ratio. Follow-on JTAGG II and III efforts are addressing the 1997/2003 IHPTET goals. A full engine demonstration of the improvements in gas turbine technology resulting from the JTAGG program will be conducted as required to be compatible with S/SU/AC requirements. Results will be improvements in performance, efficiency, and power-to-weight ratio over current production engines. The demonstration will incorporate advanced materials and materials processing, simulation and modeling, computational fluid dynamics, and manufacturing science. *Supports:* JTR, ICH, Apache, all rotorcraft, and dual-use potential.

Alternate Propulsion Sources (APS) TD (2004–10). The APS will explore advanced propulsion concepts beyond air-breathing propulsion. This program will consist of proof-of-principle technology demonstrations for propulsion concepts with potential application initially to a UAV with vertical takeoff and landing (VTOL) capability. The technology focus will explore the potential of utilizing such power sources as solar energy, high-power microwaves (HPMs), flywheel generators, and hybrids. *Supports*: UAV application.

d. Logistics/Maintenance

Survivable, Affordable, Repairable Airframe Program (SARAP) TD (2005–08). SARAP will develop, integrate, and demonstrate efforts to provide efficient and affordable airframe structures, diagnostic, and repair concepts that address tolerance to such high-intensity combat threats as NBC, directed-energy weapons (DEWs), mines, and ballistics. The survivability, performance, durability, sustainability, and serviceability of current and future VTOL aircraft will be improved through these efforts. Emerging technologies in materials, smart structures, manufacturing methods, diagnostics, and tools will be used to the fullest to obtain optimum hardening and repairability. SARAP will use integrated product and process development (IPPD), concurrent engineering, virtual prototyping, and synergistically integrated technologies to the maximum extent practicable. Some of the overall enhancements to be realized include a 50 percent improvement in high-intensity conflict survivability, a 30 percent reduction in repair times, and a 60 percent increase in aircraft combat life. *Supports:* Far-term advanced concepts and material changes to fielded systems.

On-Board Integrated Diagnostic Systems (OBIDS) TD (2000–04). The OBIDS is a showcase platform to demonstrate advanced diagnostics and prognostics. Technologies to measure, track, and analyze aircraft vibrations, stresses, pressures, temperatures, and other critical parameters necessary to assess aircraft and subsystem health and usage will be integrated into the airframe. These improved diagnostic and prognostic capabilities will be measured for O&S cost benefits and enhanced aircraft safety. The man–machine interfaces needed to present data and

generate information leading to corrective maintenance and early failure detection will be a principal focus. Technology demonstrations may encompass the design and integration of systems needed to promote the health and proper functioning of structures and dynamic components. Emphasis will be placed on improvements in maintainability and availability. *Supports:* All aircraft system upgrades and advanced concepts.

Subsystems Technology for Affordability and Supportability (STAS) TD (1997–00). The focus of STAS is on those subsystems technologies directly affecting the affordability and supportability of Army Aviation. It addresses technical barriers associated with advanced, digitized maintenance concepts, and real-time, onboard integrated diagnostics. The expected benefits from STAS are reductions in mean time to repair (MTTR), no evidence of failure (NEOF) removals, and spare parts consumption resulting in overall reductions in system life-cycle cost and enhanced mission effectiveness. Pursuits include onboard as well as ground-based hardware and software concepts designed to assist the maintainer in diagnosing system faults and recording and analyzing maintenance data and information. On-aircraft technologies will include advanced diagnostic sensors, signal processing algorithms, high-density storage, and intelligent decision aids. Shipside diagnostic and maintenance actions will integrate laptop and body-worn electronic aids, advanced displays, knowledge-based software systems, personal viewing devices, voice recognition technologies, and telemaintenance networks. *Supports:* Battle Laboratories; AH–64D, UH–60, RAH–66 upgrades; ICH, JTR; and other services and civil rotorcraft fleets.

5. Relationship to Modernization Plan Annexes

The versatility and importance of Army aviation as a member of the combined arms team will play a vital role in the Army's future modernization plans. The linkage of aviation S/SU/ACs to other AMP annexes is shown in Table III–5.

Table III–5. Correlation Between Aviation S/SU/ACs and Other AMP Annexes

System/System Upgrade/Advanced Concept		Modernization Plan Annexes: Close Combat Heavy*	Close Combat Light*	Soldier	Space & Missile Defense	IEW	C^4	Fire Support
System	RAH–66 Comanche	●	●	○	○	●	○	○
System Upgrade	Apache Longbow Modernization	●	●	○	○	●	○	○
	ICH	●	●	○				○
Advanced Concept	MULE			○	○		○	
	AMUST	●	●		○	○		○
	JTR		●	○				○

* See Combat Maneuver Annex.
● System plays a significant role in the modernization strategy
○ System makes a contribution to the modernization strategy

E. COMMAND, CONTROL, COMMUNICATIONS, AND COMPUTERS

We must strive to reap the benefits of the ongoing technology explosion, and to gain greater efficiencies in warfighting.

General John Shalikashvili
Former Chairman, Joint Chiefs of Staff

1. Introduction

The Army's command, control, communications, and computers (C^4) modernization and strategic planning efforts are an integral part of Force XXI and are critical to achieving *Joint Vision 2010*. C^4 modernization will support Force XXI by exploiting leap-ahead information transport, processing, and security technologies designed to provide commanders with overwhelming decision cycle superiority. The essential elements that ensure dominance of Force XXI C^4 are global, theater, and tactical area transport systems, a tactical internet and battle command mobile platforms, and seamless, secure, adaptable information architectures.

The Army's C^4 S&T program is directed toward providing the technologies, architectures, protocols, standards, algorithms, and software for integrating communications assets throughout the battlefield. The emphasis is placed on establishing a C^4 substructure of the digitized battlefield to provide mission planning with optimal use of resources throughout the task force. Electronic maps, resource data, intelligence information, and operational procedures are used to achieve highly automated operational planning, rehearsal, and execution with real-time command and control.

The synchronization of C^4 modernization through Force XXI, *Joint Vision 2010*, and the battle laboratories/battlefield dynamics will allow America's Army to be the best in the world—trained and ready for victory.

2. Relationship to Operational Capabilities

Table III–6 shows detailed C^4 system capabilities, noting whether they are near term (system upgrade capabilities) or far term (advanced concept capabilities). Command and control (force level and lower echelon) and communications (mobile, local, wide, and range extension), along with computing and software, are the pillars of C^4 modernization.

3. Army C^4 Modernization Strategy

Army C^4 modernization efforts support all of the Army's modernization objectives as defined in the 1996 *Army Modernization Plan.* The objectives represent a combined modernization strategy that improves or enhances existing capabilities and leverages commercial investment in information technologies.

Army modernization considers Force XXI as the Army's corporate goal of what it must become to remain the lethal force of decision through the early decades of the 21st century. It embraces the tenets of doctrinal flexibility; strategic mobility; tailorability and modularity; joint, multinational, and interagency connectivity; and versatility. The warfighter information network (WIN), in conjunction with the battlefield information transmission system (BITS) and the wireless interworking testbed (WIT), will provide the communications infrastructure for Army C^4 modernization. The goal is to provide an integrated "foxhole to sustaining base" warfighter information network consisting of communications and information services that support Force XXI requirements well into the 21st century. Significant emphasis is being placed on leveraging and adapting commercially available information technology.

Table III–6. C^4 System Capabilities

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
COMMAND & CONTROL							Integrated force and execution management	Distributed situation assessment
System Upgrade							Forecasting, planning, and resource allocation	Knowledge-based information presentation
Force Level	●	●	●	●	●	●	Platform embedded C^2	Distributed empowerment
Lower Echelon	●	●	●	●	●	●	Distributed, relational database (large area, low resolution)	Interoperability with joint assets
Advanced Concept							Automatic situation map update	Flexible hierarchical database for multiresolution, multiscales
Force XXI/Vision 2000	●	●	●	●	●	●	Replicated databases	Multimodal command understanding
							Intel order generation	Intel message preparation
							Nodal security	Expert systems
							Software bridge between different systems	• Decision aids, management system
							Automatic communications interface	• Wargaming/simulation
							Expert system battle planning	Distributed processing/databases
							• Resource allocation	Multimedia storage and retrieval
							• Concept of operation	Multimedia presentation and interface
							Expert system information correlation and fusion	Multilevel security
							Distributed database with real-time updating	Built-in training
							Interface with Army battle command system (ABCS)	Interoperability to lower echelons
							Adaptive distributed processing	C^2 on the move (OTM)
							Voice input/output	Enhanced situation awareness
							Battlefield planning	Fault-tolerant processing at critical nodes
							3D mission planning	Synchronized battle management
							Consistent battlespace understanding	Sensor integration
								Distributed processing
								Integrated position/navigation (POS/NAV)
								Heads-up display
								Automated mission planning

Table III–6. C^4 System Capabilities (continued)

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
COMMUNICATIONS							Systems control	Distributed systems
System Upgrade							• Cosite interference reduction	Dynamics rerouting
Mobile	●	●	●	●	●	●	• Embedded COMSEC	Intelligent switches
Wide Area	●	●	●	●	●	●	• Frequency management	Controllable signatures
Local Area	●	●	●	●	●	●	Gateways between local, wide area, and module systems	Wireless LAN
Range Extension	●	●	●	●	●	●	Multilevel security	Wideband multimedia communications
Advanced Concept							Fiber optic LAN	Integrated COMSEC
Force XXI/Vision 2010	●	●	●	●	●	●	Data/voice transport	User transparent
							EHF satellite communications	Cellular satellite systems
							Light satellite	Common user/satellite trunking
							Tactical multinet gateways	Airborne relay (surrogate satellite)
							RPV communications relay	Multiband multipurpose radios
							Internet controller	Transparent connectivity to local, wide, range external systems
							Surrogate satellite	Antijam EHF
							Enhanced data protocols	OTM Defense Satellite Communications System
							Conformal antennas	Militarized satellite personal communications system
							Mobile satellite connectivity	Wideband radio access point OTM SATCOM
							Personal communications system	DIS-compliant architecture
							Asynchronous transfer mode (ATM) switching	Real-time OTM planning tools
							Battlefield information transmission	Comprehensive warfighter information network
							Universal transaction communications and services	
							Assured communications	

● Provides significant capability

4. Roadmap for C^4

Table III–7 is a summary of demonstrations and SU/ACs as displayed on the roadmap (Figure III–3) for C^4 modernization. The evolution of battlefield C^4 into the 21st century begins with current C^4 systems as a baseline. In order to preserve current investments, a step-by-step block improvement approach to modernizing legacy systems is utilized. ATDs and ACTDs support the development of SU/ACs. The flow of C^4 modernization appears on the roadmap beginning with command and control and communications system upgrades on the far left, followed by specific ATDs, ACTDs, and TDs leading to Force XXI and Vision 2010.

Table III–7. C^4 Demonstration and System Summary

Advanced Technology Demonstration	Technology Demonstration
Battlefield Combat Identification	**Command and Control**
Digital Battlefield Communications	Rapid Force Projection C^2
Battlespace C^2	MOUT C^4I
Information Operations C^2 Protect and Attack	**Communications**
(See Section III–F, "Intelligence and Electronic Warfare.")	Communications Integration and Cosite Mitigation
	Multiband Multimode Radio (MBMMR)
Advanced Concept Technology Demonstration	Range Extension
	Universal Transaction Communications/Services
Rapid Terrain Visualization	Integrated Photonics
(See Volume II, Annex B, for further information.)	SATCOM Technology
	Commercial Communication Technology Testbed
System/System Upgrade/Advanced Concept	
System Upgrade	Communications—Wide Area
Command and Control—Force Level	Communications—Range Extension
Command and Control—Lower Echelon	**Advanced Concept**
Communications—Mobile	Force XXI (Vision 2010)
Communications—Local Area	

a. Technology Programs Leading to Command and Control Modernization

The following ATDs and TDs represent the Army's investment in modernizing its C^2 capabilities.

Rapid Terrain Visualization ACTD (1997–01). The goal of this ACTD is to demonstrate capabilities to collect source data and generate high-resolution digital terrain databases quickly to support crisis response and force projection operations within the timelines required by the joint force commander. The commander will be capable of integrating terrain databases with current situation data and can, therefore, manipulate and display the integrated databases, achieve operational objectives, and visualize a desired end state. Source data collection, digital terrain database generation and tailoring, database dissemination, and applications software will be integrated and evaluated. *Supports:* Joint Precision Strike Demonstration (JPSD)/RFPI, Force XXI, and Vision 2010.

Battlefield Combat Identification (BCID) ATD (1993–98). The goal of the BCID ATD is to solve the combat identification problem that surfaced in Operation Desert Storm. This ATD forms the technical foundation for the Combat Identification ACTD, which will validate the architecture for a comprehensive air-to-ground and ground-to-ground combat identification system. BCID will demonstrate improved situational awareness and various air-to-ground concepts including direct sensing target identification, "don't shoot me net," and "situational awareness through sight" approaches. Concepts for lightweight combat identification of/for the dismounted soldier will be investigated. A laser, RF- and thermal-based solution for soldier-to-soldier and potentially vehicle-interoperable application will be demonstrated (in both a standalone and integrated version). *Supports:* BCIS, Land Warrior, Protecting the Force, Battlefield Digitization, Information Warfare, and Force XXI.

Rapid Force Projection Command and Control (RFP C^2) TD (1995–98). This program will develop the command and control element for the RFPI ACTD. It consists of a reconfigurable light tactical operation center testbed (LT2) and multiple communications interfaces. Digitized

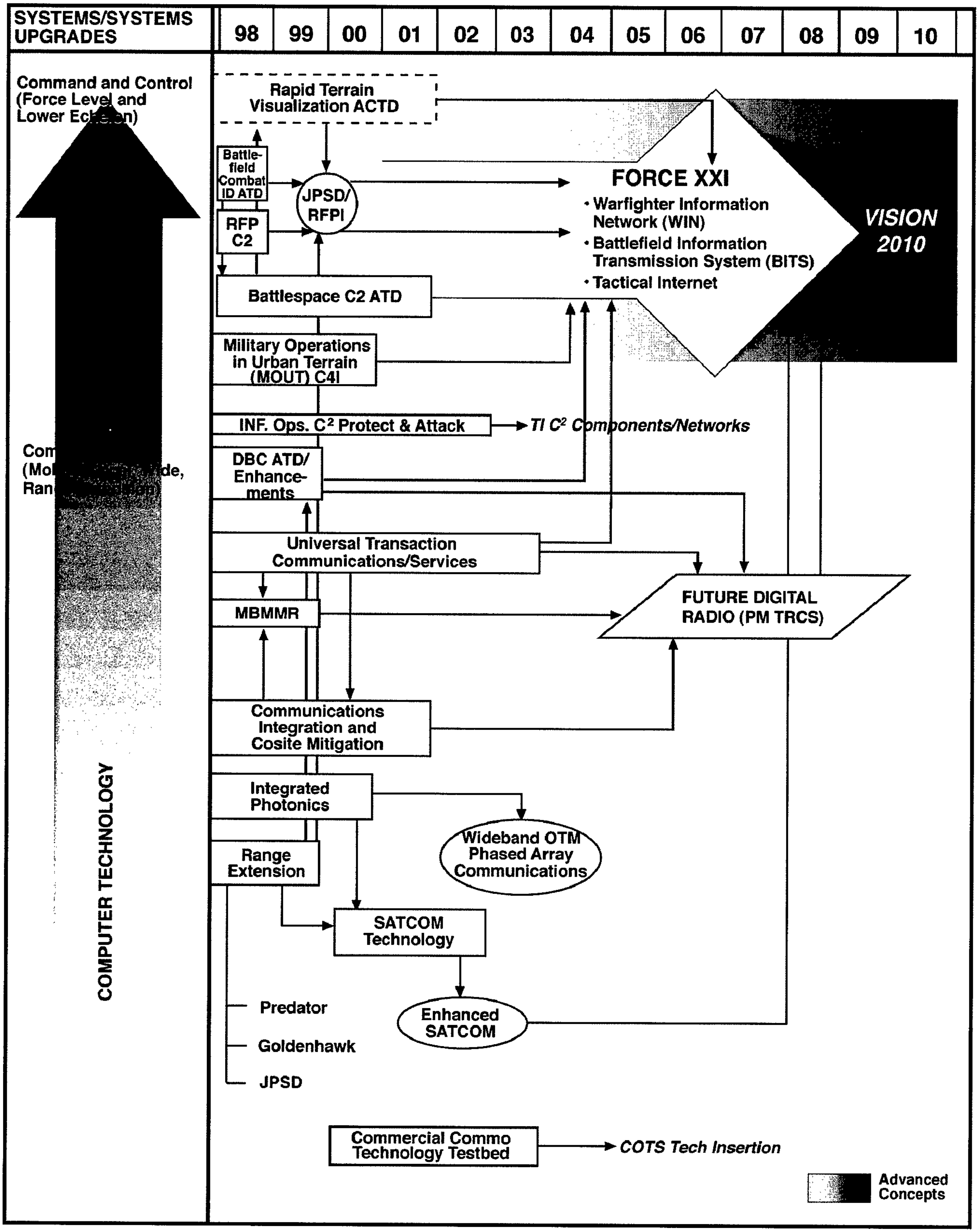


Figure III–3. Roadmap—Command, Control, Communications, and Computers

systems will link all battlefield elements from the individual soldier through the brigade and at the same time prevent communications systems information overload. The RFP C^2 demonstration will provide real-time to near-real-time integration of ACTD task force "hunters," "killers," and organic weapons; commanders; and battlefield functional area (BFA) battlefield operating systems (BOS) (i.e., All-Source Analysis System (ASAS) and Advanced Field Artillery Tactical Data System (AFATDS)). The LT2 will support target analysis, weapon-target pairings, engagement control, EFOGM fire direction, organic sensor management, commander's situation awareness, battle damage assessment, hunter/killer mission planning, near-real-time data fusion, vertical integration of command levels, and horizontal integration with other functional elements (i.e., intelligence, field artillery, air defense, armor, and dismounted soldier). *Supports:* Force XXI.

Battlespace Command and Control (BC^2) ATD (1997–01). The BC^2 ATD and its associated follow-on efforts will develop and demonstrate information- and knowledge-based technology. It will provide a common, integrated situation display with selectable detail and resolution, providing battlefield visualization and supporting systems architectures. BC^2 comprises intelligent agents for information retrieval, filtering, and deconfliction; intelligent products to support decision making; and development of systems architecture. Tri-service C^2 sources will be partitioned and distributed automatically across an integrated network of communications and computer media to provide real-time targeting, target handover, mission planning, route planning, and friendly and enemy pictures. A multiservice system architecture will interoperate with multiechelon joint/allied assets to provide faster, more accurate, intuitive, and tailored battlespace information to the mobile strike force and Force XXI. This ATD is also an integral part of the Defense Technology Objectives (DTOs) for consistent battlespace understanding; forecasting, planning, and resource allocation, and integrated force and execution management. *Supports:* Force XXI and Rapid Battlefield Visualization (RBV) ACTD.

Military Operations in Urban Terrain (MOUT) C^4I TD (1996–00). The goal of this TD is to demonstrate robust, scalable C^4I and advanced sensor capabilities that provide commanders and warfighters with seamless, nonhierarchical adaptive networks for multimedia communications in a highly dynamic MOUT environment. The objective is to evolve an integrated communications infrastructure that leverages commercial protocols, formats, waveforms, and standards to achieve global tri-service interoperability through integration of mobile Internet protocol (IP) tactical networks into global infrastructure. MOUT C^4I will demonstrate near-real-time vertical and horizontal C^2 from the battalion down to the individual combatant. *Supports:* Force XXI Land Warrior.

Information Operations C^2 (IOC^2) Protect and Attack ATD (1998–02). This ATD will demonstrate the ability to launch effective C^2 attacks against threat information systems and protect the Army's tactical information systems from modern network attacks. See Section III–F, "Intelligence and Electronic Warfare," for details on this program. *Supports:* Integrated Countermeasures, Tactical Internet (TI) C^2 Components, and Networks.

b. Technology Programs Leading to Communications Modernization

Communications, specifically seamless communications, facilitates command and control. C^2 would be impossible without the ability to communicate (i.e., transmit and receive strategic, tactical, and operational information in a timely manner to and from the commander and associated staff). Several 6.2 programs are under way to facilitate and implement Army 6.3 communications efforts, including a personal communications system (PCS), antennas for communication across the spectrum, and advanced modeling and simulation (see Chapter IV for details on 6.2 programs). The following ATDs and TDs reflect

the Army's current strategic plan for communications modernization.

Digital Battlefield Communications (DBC) ATD (1995–99). This ATD will exploit emerging commercial communications technologies to support multimedia communications in a highly mobile dynamic battlefield environment, the "digitized battlefield," and split-based operations. Commercial asynchronous transfer mode (ATM) technology will be integrated into actual tactical communications networks to provide bandwidth on demand to support multimedia information requirements. To extend ATM services to forward tactical units, a radio access point (RAP) will be prototyped and tested. The RAP utilizes a high-capacity, OTM trunk radio to feed a variety of mobile subscriber services. Both manned and unmanned aerial platforms will be fitted with wideband relay packages to support OTM tactical operations, supporting bandwidths of up to 155 megabytes per second (MBps). This ATD will conclude in FY99 with the insertion of appropriate technology products (high-capacity digitized communications and split-based operations) in Corps XXI advanced warfighting experiment (AWE). A parallel effort, DBC enhancements (1996–99), includes an earlier demonstration of the direct broadcast satellite (DBS) technology (in support of Joint Warfighter Interoperability Demonstration (JWID) 96 and Task Force XXI). An effort to exploit terrestrial PCS was added to the program at the request of the Army Digitization Office, and will be used to exploit commercial code division multiple access (CDMA) and broadband CDMA (BCDMA) technology as a wireless private branch exchange (PBX) off a mobile subscriber equipment (MSE) switch for command post voice and data subscribers. Multilevel security requirements for Force XXI will be addressed by the insertion of tactical end-to-end encryption device (TEED) hardware. Wideband HF technology will be evaluated, tested in a digital integrated laboratory environment, and inserted into Division XXI AWE. *Supports:* All Transport Systems, Force XXI, and Future Digital Radio (FDR).

Universal Transaction Communications/ Services TD (1996–03). Seamless connectivity and integration across communications media will be demonstrated. The goal is to provide the commander the ability to exchange and understand information unimpeded by differences in connectivity, processing, or systems interface characteristics. It will allow information to flow from wherever it exists, in whatever form, to wherever it is needed, in whatever form it is needed. Attributes include automated interfaces, techniques for enhancing the commercially available signal conditioning, provision of dynamic profiles and adaptive conditioning, and automatic, adaptive addressing to allow connections to users completely independent of any knowledge of location. *Supports:* All tactical communications, a tactical internet, and Force XXI.

Multiband Multimode Radio (MBMMR) TD (1995–99). The MBMMR is a joint service program to develop the baseline architecture and technology for the objective MBMMR, meeting the requirements of FDR. MBMMR will demonstrate a highly flexible radio architecture, allowing rapid waveform reprogrammability/reconfigurability to support the rapidly changing mission requirement of electronic warfare (EW) threats, interoperability, networking, traffic load, frequency assignment, and general modes of operation. Technology insertion includes the use of advanced digital signal processors (DSPs), programmable four-channel CYPRIS chip information security (INFOSEC) modules, and interference cancellation (cosite) circuitry. The MBMMR will utilize an open (industry releasable) system architecture. A highly software reprogrammable (waveform and INFOSEC) radio will provide four simultaneous MBMMR channels and networking functions, thus minimizing the required number of antennas. *Supports:* FDR and Force XXI.

Communications Integration and Cosite Mitigation TD (1997–01). The objective of this demonstration is to reduce the size, weight, power, and cosite interference problems that occur when multiple radios in either the same or

dissimilar frequency bands are integrated within a communications system. The physical space constraints of mobile platforms cause these problems to be even worse. Technology from ongoing developments will be coupled with new efforts to address the problem within the continuous frequency band from 2 MHz to 2 GHz while also attacking the cosite interference in the HF, VHF, and UHF bands. Development efforts include VHF and UHF multiport antenna multiplexers, ancillary cosite mitigation devices, and wideband linear power amplifiers. Additionally, a multiband communications system will be integrated within a typical Army single integrated command post (SICP) shelter mounted on a high-mobility, multipurpose wheeled vehicle (HMMWV), and tests will be performed to evaluate the resultant performance and enhancements. This testbed will be exercised throughout the FY99–FY01 period for evaluation of the individually developed items. *Supports:* All mobile multiband communications systems and Force XXI.

Range Extension TD (1997–99). This program directly supports the Army C^4 modernization "key azimuth" of range extension through the development and integration of a multitude of satellite communications (SATCOM) and related technologies. It will identify and develop key technologies required for airborne applications of a suite of communications packages, design and integrate specific systems, and conduct system tests and demonstrations of intratheater communications range extension at a variety of data rates. Major technology areas to be addressed are airborne payload (including antennas) designs, ground terminal adaptations, interoperability/compatibility, and simulation. These technologies will be used to supplement current (and programmed) SATCOM resources at all frequency bands. SATCOM terminals will be augmented and enhanced to provide the capability of communicating via satellite or airborne platforms. The utility of SATCOM terminals will be extended by improvements to reduce size and weight, increasing throughput and mobility, and implementing emerging techniques such as demand assignment multiple access (DAMA). A super high frequency (SHF) surrogate satellite system will be demonstrated in FY98. In FY99, a UAV-based EHF and airborne battlefield paging capability will be demonstrated. *Supports:* Joint Project Office (JPO) UAV TIER II Program, Goldenhawk, and Joint Precision Strike.

Integrated Photonics TD (1995–00). This effort will develop integrated photonic subsystems for application to optical control of single-beam phased-array antennas and fiber optic point-to-point links, local area networks, and antenna remoting systems. Subsystems will be developed for optical control of multibeam phased-array antennas. These subsystems will reduce size, cost, and power consumption while increasing the performance of high-speed fiber-optic systems. Demonstration of a photonically controlled, multipanel, phased-array antenna will be conducted during FY00. *Supports:* SATCOM OTM.

SATCOM TD (2000–02). This technology effort will extend the applications and capabilities of SATCOM terminals by providing higher data rates, improvements in throughput, and reduction in life-cycle costs. Throughput improvement will utilize emerging techniques and architectures, such as DAMA, on a per-call basis. Overall improvements to systems and equipment will reduce size and increase mobility for military and commercial SATCOM terminals. *Supports:* SATCOM upgrades.

Commercial Communications Technology Testbed (C^2T^2) TD (2000–03). C^2T^2 is designed to take advantage of breakthroughs in commercial communications technology and assess their utility for military applications. The objective is successful technology insertion. It provides a means for rapidly evaluating and characterizing commercial products. The most promising candidates are introduced to the battle laboratories and field users for evaluation, then incorporated into warfighting experiments. The three-phase evaluation process includes standalone evaluation, Digital Integrated Laboratory (DIL) integration,

and an AWE. *Supports:* COTS technology insertion.

c. Computer Technology

Computer technology, the fourth "C" in C^4, forms the underpinnings of most, if not all, C^3 systems today and in the future. The computing and software technology area is focused on novel computer hardware and integrated systems for Army applications. The Army's computing technology programs include scalable parallel systems and applications, high performance specialized systems and applications, and networks and mobile computing. Details on these programs and more on computing and software technology may be found in Chapter IV, "Technology Development."

5. Relationship to Modernization Plan Annexes

Table III–8 shows the correlation between C^4 modernization efforts and other AMP annexes. C^4 permeates throughout the other Army mission areas (i.e., aviation, IEW, mounted/dismounted forces, soldier, air defense, theater missile defense (TMD), close combat light, fire support, logistics, training, NBC, space, and combat health support). C^4 facilitates the Army's capability to project, sustain, and protect the force, win the information war, conduct precision strikes, and dominate the maneuver.

The Army's continued pursuit of emerging C^4 state-of-the-art communications-electronics technologies guarantees the stability of the United States' defense posture and the safety of its most valuable asset, the warfighter.

Table III–8. Correlation Between C^4 S/SU/ACs and Other AMP Annexes

System/System Upgrade/Advanced Concept		Modernization Plan Annexes											
		Mounted/Dismounted Forces*	Aviation	Fire Support	Space & Missile Defense*	Close Combat Light*	IEW	Soldier Systems	Space	Logistics	Training	NBC	Combat Health Support
System Upgrade	C^2—Force Level	○		●	○		●		●	●			
	C^2—Lower Echelon	●	○	○		●	●	●	○	●		○	●
	Communications—Mobile	●	●	○	●	●	○	●	○	●			○
	Communications—Wide Area	○		○		○			●	●			
	Communications—Local Area	●	○	●	○	●	○	○	○	●		○	○
	Communications—Range Ext	○	○		○				●	●			
Advanced Concept	Force XXI/Vision 2010	●	●	●	●	●	●	●	●	●	○	○	○

* See Combat Maneuver Annex.
● System plays a significant role in the modernization strategy
○ System makes a contribution to the modernization strategy

F. INTELLIGENCE AND ELECTRONIC WARFARE

Knowledge itself is power.

Francis Bacon

1. Introduction

Commanders require dynamic intelligence support tailored to their specific mission requirements. Intelligence must be timely to enable them to make informed decisions for the simultaneous application of decisive combat power across the depth and breadth of their areas of responsibility. The key to their ability to apply focused and synchronized combat power is a seamless intelligence system enabling them to utilize all of the capabilities of the intelligence community, including national agencies, theater assets, and organic capabilities to see the battlefield and target high-payoff enemy targets accurately.

Intelligence (Intel) XXI is the Army intelligence vision supporting Force XXI, created to provide intelligence support to warfighters at all echelons, joint and ground component commanders, and coalition forces across the continuum of 21st century military operations. This vision provides commanders with a knowledge-based, prediction-oriented, and operationally flexible intelligence system. Intel XXI is focused on intelligence support for the force projection Army in the information age of the 21st century.

The focus of Intel XXI is on the presentation of intelligence in a way that immediately conveys an understanding of the battlespace and the significance of the intelligence presented. Underlying the focus on presentation is an operationally flexible system executing an expanded intelligence cycle (present, manage, collect, process, and disseminate) in a more rapid and focused way to provide the commander what is needed, when it is needed, melded with his operational plan. The essence of intelligence is the ability to reduce uncertainty and provide an understanding of the battlefield through effective presentation. Intel XXI will enable us to leverage information age technology to do exactly that.

Based upon doctrinal underpinnings, the Army conducted a force design update for both the active and reserve component military intelligence force structure. The objective was to create a seamless system of intelligence systems from national to maneuver-battalion level. To meet the targeting challenges of the 21st century, key information and a common view of the battlespace will be sent to all commanders immediately, emphasizing graphic rather than narrative reporting. This integrated battlefield will be visually portrayed throughout its width, depth, and height, with sensor input sufficiently accurate to permit precision targeting.

Counterintelligence (CI) and human intelligence (HUMINT) are integral to intelligence and electronic warfare (IEW) and contribute to the warfighters' ability to conduct operations by denying information to enemy weapon and information-gathering systems, deceiving the enemy regarding the battlefield situation, and developing unprecedented environmental awareness and force protection predictability.

Meeting the warfighters' demands for timely, accurate, and relevant targeting information requires a future intelligence architecture built upon these key modernization concepts. Our goal is:

- One family of UAVs to fix targets.
- One airborne system to look deep.
- One division sensor system that does it all.
- One all-source analysis system that fuses it all.
- One processor to exploit national capabilities.
- One common ground station to conduct the fight.

The research, development, and fielding of this new generation of intelligence systems is a continuous process. The intelligence force capabil-

ities provided by our modernization program give us a more balanced and capable force. Planned S/SU/ACs will provide the operational capabilities that will ensure our spectrum supremacy and allow us to win the information war.

2. Relationship to Operational Capabilities

In Table III–9, detailed IEW system capabilities are summarized; the S/SU capability column refers to relatively near-term capabilities, the AC capability column presents far-term goals. Correlation between these system capabilities, the IEW S/SU/ACs, and the Army modernization objectives is also displayed.

3. IEW Modernization Strategy

The modernization of Army intelligence and electronic warfare systems is discussed in Annex D, IEW, to the AMP. It develops a strategy for an open systems architecture to allow for continuous modernization of the IEW mission area to provide multimission systems on common carriers for a complementary mix of airborne, ground-based, and cross-forward line of own troops (FLOT) sensors, processors, and jammers. The goal of IEW modernization is to provide the Army with the most capable IEW systems in the world, while developing future systems to meet the challenges of the 21st century.

As noted in the introduction to this section, Intel XXI is the intelligence vision that supports Force XXI. Its intent is fundamentally based on the requirement to provide intelligence support to warfighters and joint and ground component commanders across the continuum of the 21st century military operations, with emphasis on how intelligence will support our force projection Army in the information age. The basic requirements that the vision supports are battle command, extended battlespace dominance (understanding the information battlefield, C^2 exploit, C^2 attack, and C^2 protect), force projection, and operational flexibility.

Key to battle command and battlespace dominance is information presentation to the commander in the form of visual displays. Intel XXI's three primary objectives are to provide to the commander a virtual, near-real time, continuous picture of the battlespace, intelligence support for targeting, and battle damage assessment. These objectives drive requirements for sensors, processors, and communications capabilities.

To accommodate the requirements of the future, IEW must use the Army's RDA concept and enabling strategies to guide its efforts. Today's technology is not sufficiently capable of fully satisfying Force XXI intelligence requirements. Efforts are under way to consolidate and accelerate several disparate programs in order to field key capabilities in the following technology areas: displays, computer hardware, software, visualization databases, sensors, automatic target recognition, and networks.

The capabilities described in this plan are augmented by the National Foreign Intelligence Program: general defense intelligence, consolidated cryptologic, and foreign counterintelligence programs.

4. Roadmaps for IEW Systems

Table III–10 presents a summary of IEW TDs, ACTDs, ATDs, and S/SU/ACs as found in the IEW roadmaps. Systems and system upgrades are the first step in fulfilling the IEW strategy. These will evolve from current systems through the use of product improvement programs (PIPs) and P^3Is. Technology demonstrations and ATDs will be utilized to facilitate the transition of technology through block improvements to existing or new systems. The challenge is to field a family of IEW systems that use a common module open architecture, thus improving flexibility, reducing the logistics burden, and minimizing development costs.

For the far-term, future systems planning is focused on the integration of IEW systems with command, control, and communication systems into one C^3 IEW "system-of-systems," which will

Table III–9. IEW System Capabilities

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
CLOSE RSTA							(ELINT, COMINT, and electronic attack (EA) radar multisensor package Sensor to detect, track, and classify vehicles and personnel UAV penetration and stand-in reconnaissance, surveillance, and target acquisition (RSTA)/EW modular payload	Integrated system of sensors and collectors Survivable • All weather • All echelons Mobile Flexible and adaptable Multiplatform • Ground based • Airborne Multispectral and integration • Imagery assessment • Acoustic • Radar • Laser • COMINT • ELINT • HF–EHF Accurate • Range • Location • Percent detected Modular • Common platforms • Common hardware and software Onboard preprocessing
System								
Ground-Based Common Sensor—Heavy*		○	●	○	○			
Ground-Based Common Sensor—Light		○	●	○	○			
Tactical UAV Intel Package		○	●	○	○			
System Upgrade								
Advanced QUICKFIX		○	●	●	○			
Advanced Concept								
Integrated Intercept		○	●	○	○			
Integrated Sensor		○	●	●	○			
DEEP RSTA (GROUND/ AIRBORNE)							Manned aircraft with multipurpose RSTA sensor suite Airborne SIGINT/IMINT/radar/ELINT/MASINT collection system for midrange emitter mapping UAV modular sensor (imagery, meteorological, NBC) with cross-cueing/processing UAV stationary target ID sensor classification	
System Upgrade								
Enhanced Trackwolf		○	○		○			
Advanced Concept								
Integrated Intercept		○	●	○	○			
Integrated Sensor		○	●	●	○			

Table III–9. IEW System Capabilities (continued)

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
PROCESSING & FUSION							Situation development target engagement Intel OTM antenna upgrades Automated weather decision aids	Mapping propagation Single, multiple, and all-source processing Intelligent information • Correlation and fusion • Expert systems • Decision aids • Artificial intelligence • Target identification • Target nominations • Situation analysis Information dissemination • Multiechelon • Closed-loop target handoff Common modules • Hardware and software • Built-in training
System Upgrade								
ASAS Upgrades			●	●	○			
Integrated Meteorological System	○	○	●	○	○			
Meteorological Measuring Set	○	○	●	○	○			
Advanced Concept								
Distributed IEW Fusion			●	●	○			
Profiler	○	○	●	○				
ELECTRONIC ATTACK/ PROTECTION							Stand-in UAV HF–UHF and beyond (threat dependent) Standoff Long range electronic attack Active passive cooperative target ID Vehicular self-protection Aircraft self-protection/suppression of enemy air defense (SEAD) Laser warning IRCM HPM/MMW • Aircraft protection Jammer family • Communications, noncommunications • Multisignal • Multispectral autonomous Standoff	Penetration Implanted Expendable Active/passive noncooperative IFF Protection against • Ground based • Airborne • Space bases • Radar, IR EO Onboard C^2 integration Laser beamrider warning/ CM
System								
Tactical UAV Intel Package		○	●	○				
Ground-Based Common Sensor—Heavy		○	●	○	○			
System Upgrade								
Advanced QUICKFIX*		○	●	●	○			
Advanced Concept								
Common Air/Ground Electronic Combat Suite		●	●	●	○			

● Provides significant capability ○ Provides some capability * Contains communications jamming capability

Table III–10. IEW Demonstration and System Summary

Advanced Technology Demonstration	Technology Demonstration
Multispectral Countermeasures (see Aviation) Tactical C^2 Project Multimission/Common Modular UAV Sensors	**IEW Ground-Based Collection Demonstrations** Impulse/Wideband Electronic Support (ES) Advanced ES Receiver Modern Communications A/D Beamformer ES/EA **IEW Airborne Collection Demonstrations** Orion SAR Target Recognition and Location System **Intelligence Processing and Fusion Demonstrations** Multiple Source Correlated Intelligence Fusion Demonstration Owning the Weather Tactical Intelligence Data Fusion Techniques **Information Denial Demonstrations** Advanced Digital Electronic Attack SAR Deception Techniques C^3 Warfare Techniques Modern C^2 Warfare Integrated Sensors and Targeting Integrated Countermeasures
Advanced Concept Technology Demonstration	
Joint Precision Strike Demonstration—Precision/Rapid Counter MRL ACTD (For additional information, see Volume II, Annex B.)	

System/System Upgrade/Advanced Concept	
System Ground-Based Common Sensor—Heavy Ground-Based Common Sensor—Light (Land Warrior SIGINT Division) Tactical UAV Intelligence Package **System Upgrade** Advanced QUICKFIX (Aerial Common Sensor—Division) ASAS Upgrades Enhanced Trackwolf	Integrated Meteorological System Integrated Countermeasures Meteorological Measuring Set **Advanced Concept** Integrated Intercept System Integrated Sensor Sensor Distributed IEW Fusion Profiler Common Air/Ground Electronic Combat Suite

carry out the presentation, management, collection, processing, dissemination, transport, and denial of battlespace information.

The following sections contain roadmaps that lay out the required program efforts in information collection (Figures III–4 and III–5), information processing (Figure III–6), and information denial (Figure III–7). Each section contains descriptions of associated technology demonstrations that support IEW S/SU/ACs.

Most of the demonstrations directly support the systems that form the basis of the IEW annex to the AMP. The remaining demonstrations represent initiatives that support a variety of IEW systems, or are technology programs supporting non-MI systems not specifically addressed in the IEW annex to the AMP.

a. Technology Programs Leading to Information Collection for IEW Ground-Based Collection Systems

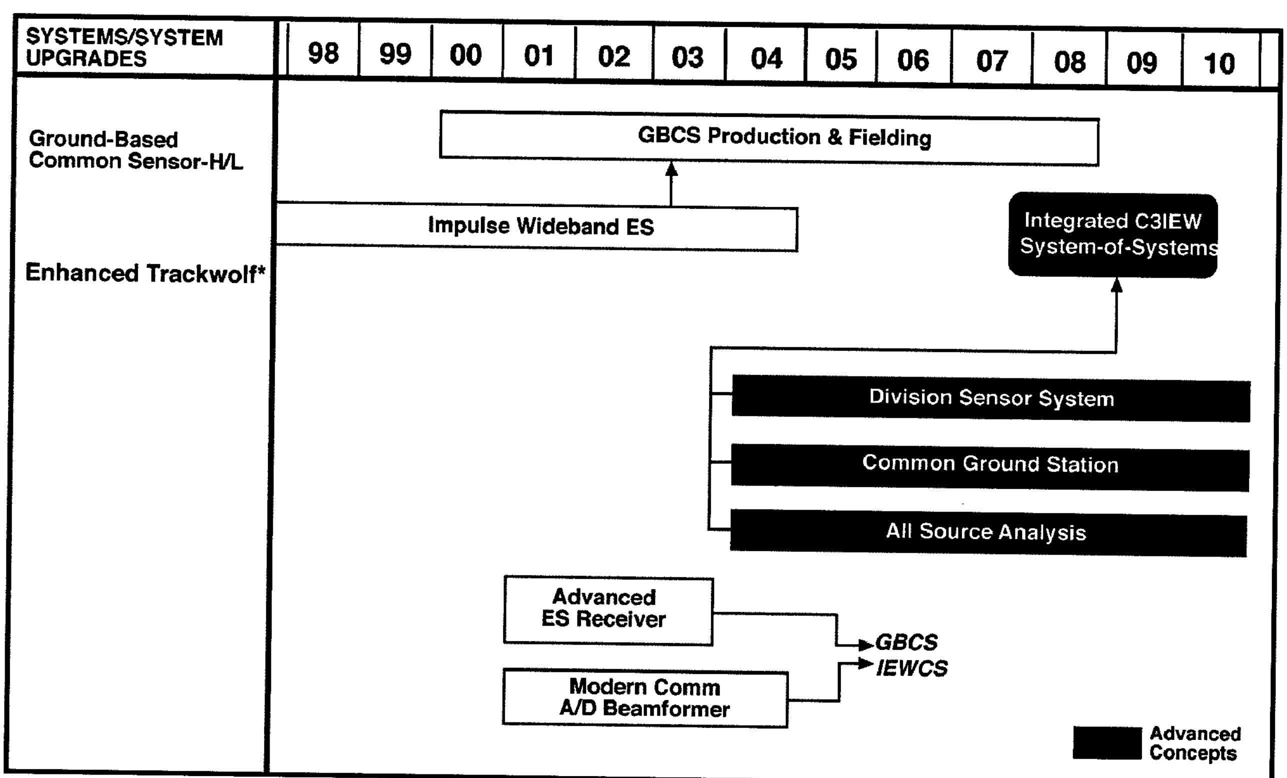
Ground-based collectors for IEW ground-based collection systems are targeted against multiple echelons. They embody modular, scalable, multisensor capabilities that combine ELINT, COMINT, and EA. The mixture of systems ranges from transportable to manpack.

Each provides surveillance, targeting, and intelligence data to be correlated with data provided by other sensors. The roadmap for ground-based collection systems is shown in Figure III–4.

Impulse Wideband Electronic Support (ES) TD (1997–04). This demonstration will focus on developing advanced techniques to detect, characterize, and geolocate impulse radars in the presence of conventional radars and communication signals. Impulse radars represent a significant advance in the state of the art for battlefield radars. Since they were developed to counter detection, location, and destruction, current countermeasures are ineffective against them. This work will involve a coordinated effort that includes tri-service and international participation, as well as the use of the SBIR program. The objective of these programs is to develop technology for insertion into current and future ES systems to counter the emerging impulse radar threat. *Supports:* Ground-Based Common Sensor.

Advanced Electronic Support (ES) Receiver TD (2000–03). This program will demonstrate a digital reconfigurable receiver to accommodate a variety of missions. This digital channelized receiver is intended to upgrade the intelligence and electronic warfare countermeasures suite (IEWCS) front end to intercept very wideband signals in a single-channel mode, as well as to resolve narrowband signals spatially in a multichannel mode. This ensures exploitation of modern communication signals and efficient allocation of system resources. *Supports:* IEWCS and GBCS.

Modern Communications Analog/Digital (A/D) Beamformer Electronic Support/Electronic Attack (ES/EA) TD (2000–04). The ability to resolve targets spatially using beamforming developments will increase the standoff ranges in which communications collection can occur, or provide greater system sensitivity for signals at lower signal-to-noise ratios at current standoff ranges. This program will demonstrate the effec-



* System upgrade.

Figure III–4. Roadmap—IEW Ground-Based Information Collection Modernization

tive use of this technology to address the frequency reuse or cochannel interference problem in modern communications collection and identification to support electronic attack issues. *Supports:* IEWCS and GBCS.

b. Technology Programs Leading to Information Collection Modernization for IEW Airborne Collection Systems

The roadmap for airborne information collection shows a mixture of manned and unmanned platforms. The manned aircraft will undergo preplanned product improvements that will add required capabilities on an incremental basis. Unmanned airborne vehicles will carry a variety of IEW sensor packages. The roadmap is shown in Figure III–5.

JPSD Precision/Rapid Counter Multiple Rocket Launcher (MRL) ACTD (1995–98). This mature ACTD has demonstrated a significant enhanced capability for U.S. Forces Korea (USFK) to neutralize the North Korean 240-mm MRL system. Because the 240-mm MRL is a mobile and fleeting target, it is expected to be exposed and vulnerable to counterfire for very short time periods. It is an extremely sensitive, time-critical target (TCT), requiring nearly continuous surveillance and nearly instantaneous target acquisition. The realities of terrain on the Korean peninsula require that a sensor be overhead and

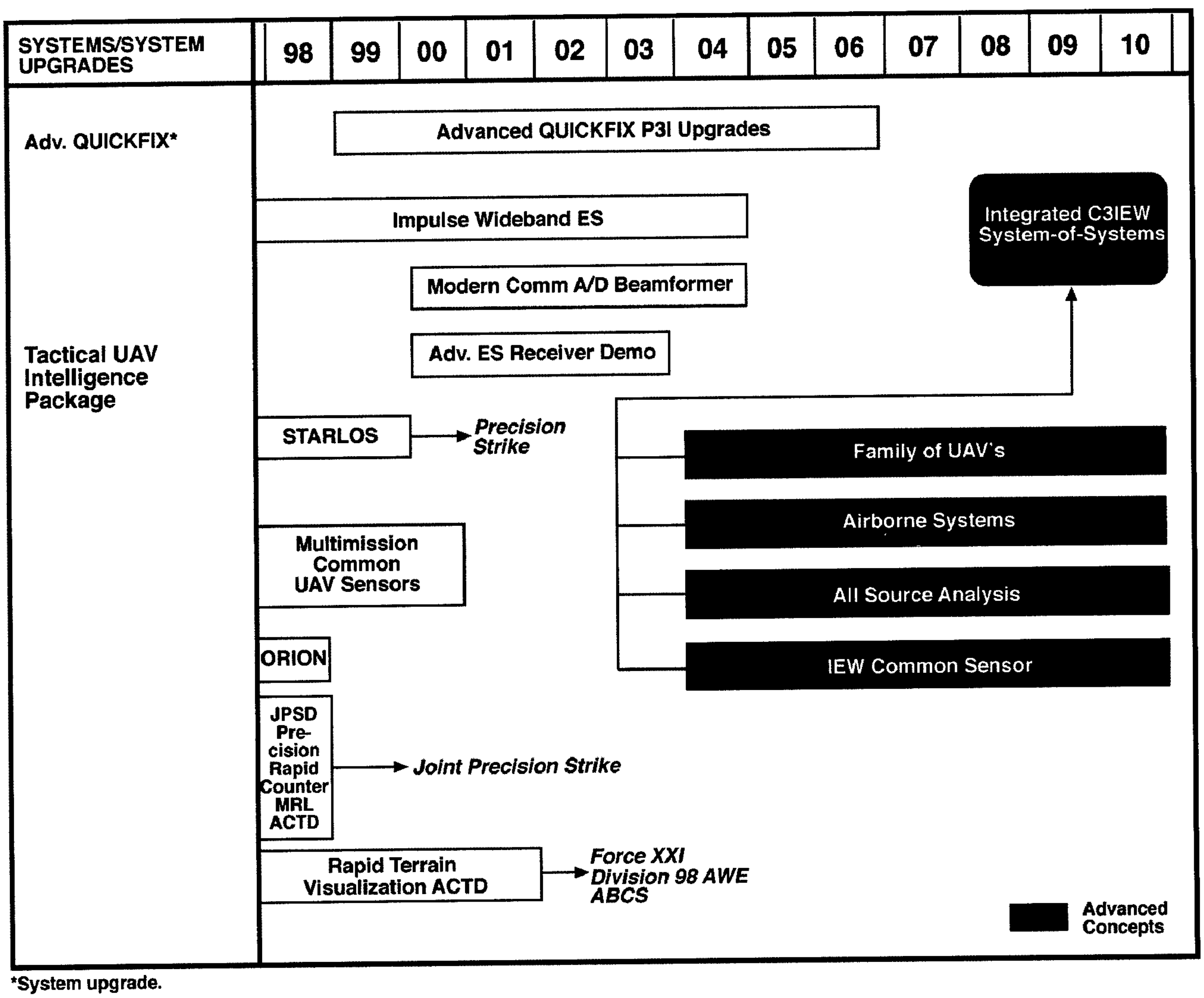


Figure III–5. Roadmap—IEW Airborne Information Collection Modernization

that target information be made available to the firing unit most capable of hitting the 240-mm MRL in the least possible time. A second-generation IR line scanner called the Reconnaissance Infrared Surveillance and Target Acquisition (RISTA II for second generation) was developed with an Aided Target Recognizer and Processor (AiTRAP). This system provides high-resolution, wide-area coverage, and automatic target chip presentation to a targeteer. The system was proven in FY96 at a demonstration at Fort AP Hill. The system was to be integrated on a Hunter UAV, but reconfiguration of the DoD UAV program precluded Hunter availability. Plans are to demonstrate it at Fort Hunter Ligget on an ALTUS Predator UAV. The sensor leave-behind for the counter multiple rocket launcher (CMRL) problem is an Aided Target Recognizer for application to TESAR. The AiTRAP will cue the targeteer to 240 MRL targets. A preliminary demonstration of this capability was shown in FY96 at Fort AP Hill. A demonstration of real-time SAR ATR against 240 MRL targets will occur in 4QFY97. The first leave-behind will be a Challenger-based system for CONUS Predator systems in FY97, and the second leave-behind will be a COTS processor in the Predator ground control station (GCS) for OCONUS deployment. *Supports:* Joint Precision Strike and Joint Attack Operations.

Multimission/Common Modular UAV Sensors ATD (1997–01). This ATD will provide a low-cost, lightweight, EO/IR integrated MTI radar/SAR payload for integration on future tactical UAVs. The radar payload will build upon successes in the current low-cost radar development program and will likely utilize monolithic microwave integrated circuit (MMIC). The FLIR will take advantage of high quantum efficiency, 3–5-micron staring arrays. These sensor payloads will provide enhanced reconnaissance, surveillance, battle damage assessment, and targeting for non-line-of-sight weapons. Demonstrations will focus on multiple mission flexibility in support of early entry and deep attack forces. *Supports:* Tactical UAV Intel Package.

Impulse Wideband Electronic Support TD (1997–04). See description in the Ground-Based Collection Systems subsection above.

Orion TD (1995–98). This program will demonstrate the operational effectiveness of a wide bandwidth SIGINT ES package on a surrogate UAV platform operating in conjunction with a ground-based IEW common sensor that receives the UAV ES-detected signals and performs the intercept/processing task to locate high value C^2 targets, thus enhancing the capabilities of the IEW common sensor by allowing deeper penetration of the enemy's communications space to detect even low signal levels from directional systems such as multichannel. The system will also allow the intercept of modern low-power communications. Collection of these signals is difficult due to low radiated power. Orion provides needed access to these signals. There are also plans to include EA into the package to provide a unique capability to attack deep targets and assist in the execution of information warfare missions against critical deep targets. *Supports:* Tactical UAV Intel Package.

Advanced ES Receiver Demonstration and Modern Communications Beamformer ES/EA Demonstration TD (2000–04). See description in the Ground-Based Collection System subsection above.

Synthetic Aperture Radar (SAR) Target Recognition and Location System (STARLOS) TD (1994–99). This program will develop real-time aided/ATR capabilities and demonstrate their functionality in a number of different platforms using SAR as sensor. The ATR capabilities will be demonstrated in the ground station for the aerial platforms and will concentrate on the detection, classification, recognition, and identification of high-value, high-payoff targets. The program will provide location of time-critical targets in day/night and most weather conditions using wide-area coverage rates. Since multiple platforms will be addressed, the ATR algorithms will be implemented using scalable common ATR hardware. In addition, the scalable hardware will be used to execute algorithms for other sensors

including second-generation FLIR/line scanner (LS), thus allowing more platforms (both intelligence and combat weapon) to be considered for potential ATR insertion using the principles of HTI. *Supports:* Precision Strike, Medium-Altitude Endurance UAV, and Tactical UAV Intel Package.

c. Technology Programs Leading to Intelligence Processing and Fusion Modernization

The objective of intelligence fusion and processing modernization is the development and fielding of common hardware and software for intelligence analysis centers. The goal is to shorten timelines for supplying intelligence to the commander and to provide real-time target information to weapon systems. The roadmap is shown in Figure III–6.

Tactical Intelligence Data Fusion Demonstration TD (1996–00). The objective of the program is to demonstrate automated tactical data fusion concepts and technology and to establish the effectiveness of these tools as an intelligence force multiplier for the commander. Enhanced military intelligence collection and asset management tools, terrain reasoning tools, enhanced information dissemination tools and techniques, and battle damage assessment (BDA) tools and techniques will be developed and integrated into existing IEW systems. IEW asset management and intelligence preparation of the battlefield (IPB) tools and techniques have been successfully demonstrated at Task Force XXI. Future plans include the demonstration of multiple source fusion using SIGINT and MTI radar data. Simulation tools will be used to evaluate the use of information from nonconventional sources such as the airborne survivability equipment (ASE) to enhance intelligence collection. Ultimately, advanced airborne planning algorithms and effectiveness tools will be integrated into IEWCS multisensor tasking and reporting tools using database-to-database interfaces. These tools will allow the commander to receive timely, correlated information allowing operations within the enemy's decision cycle. *Supports:* ASAS and IEWCS.

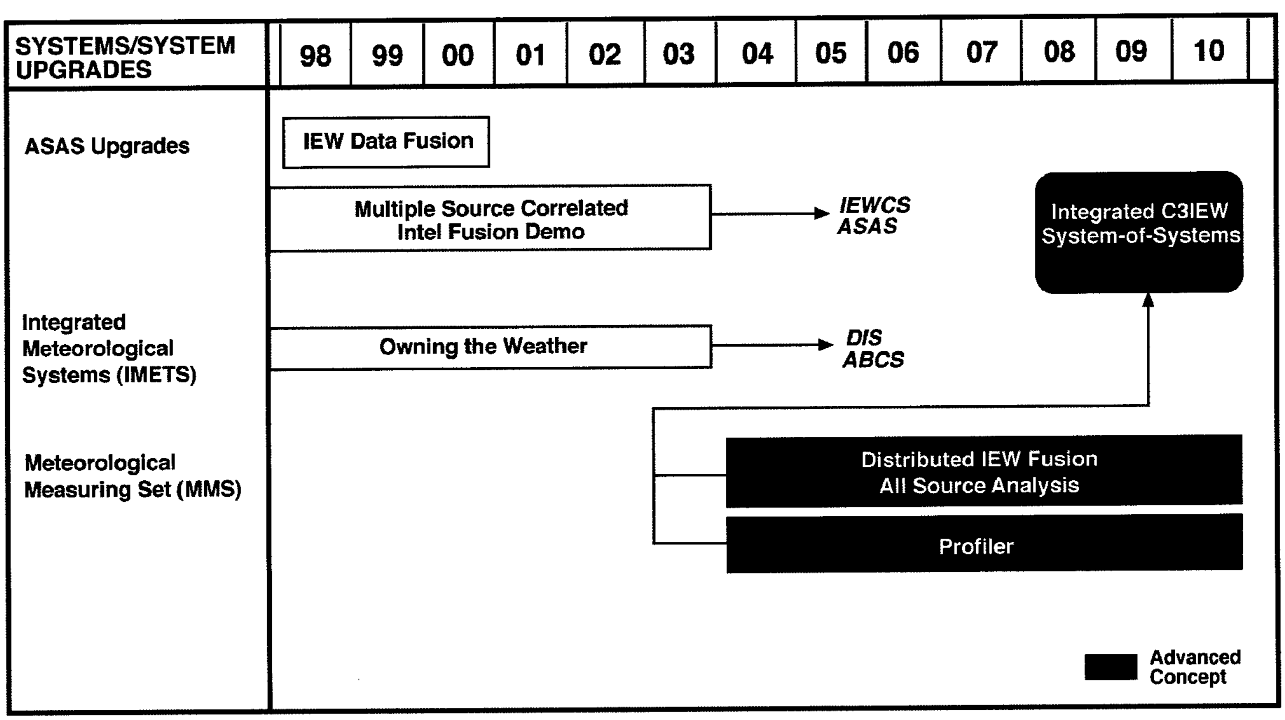


Figure III–6. Roadmap—IEW Fusion Information Processing Modernization

Multiple Source Correlated Intelligence Fusion Demonstration TD (1999–03). This effort will demonstrate a fully integrated tactical intelligence data fusion module at corps and division levels. The module will be stimulated with diverse inputs and perform various fusing functions to provide the commander with a comprehensive visualization of the battlefield using advanced, multimedia display techniques to provide complete status of the situation in an easily viewed and understandable format (status at a glance). Inputs to the module will be from the entire suite of battlefield sensors and both tactical and strategic intelligence sources. Sensors will be queued, and remote resources queried, to synchronize the fusion effort with the supported tactical operation. Data will be correlated using advanced fusion techniques, such as automated terrain reasoning, for location and movement analysis and amalgamated into intelligence products. This module will support functions from the initial IPB to final BDAs and will also assist in fratricide prevention. *Supports:* ASAS and IEWCS.

Owning the Weather TD (1996–03). This program consists of three interrelated TDs that will transition directly from 6.2 into the integrated meteorological system (IMETS) and the field artillery's meteorological measuring set (MMS), the advanced concept profiler, Army battle command system (ABCS), battlefield automated systems (BASs), and the modeling and simulation (M&S) community. The first TD, target area meteorology, will upgrade IMETS and MMS with a battlespace forecasting capability and add computer-assisted artillery meteorology software to the MMS and future profiler for improved accuracy of indirect fire and precision strike. The profiler will replace balloon-borne measuring systems and hydrogen generators on the battlefield. The second TD, automated decision aids, will enable commanders to apply this improved knowledge of battlefield weather to compare weather-based advantages/disadvantages of friendly and threat systems using automated decision aid client applications on ABCS BASs served by the IMETS through a distributed computing environment. Automated weather decision aids were used effectively in the Brigade Task Force XXI AWE 2QFY97 to demonstrate the utility of the client server architecture. The third TD extends the target area meteorology and decision aid technology to the M&S environment so that realistic operational battlescale forecast weather and predicted impacts on systems and operations are also useable in mission rehearsal, training, and combat simulations. *Supports:* IMETS, MMS, Profiler, ABCS, and Distributed Interactive Simulation.

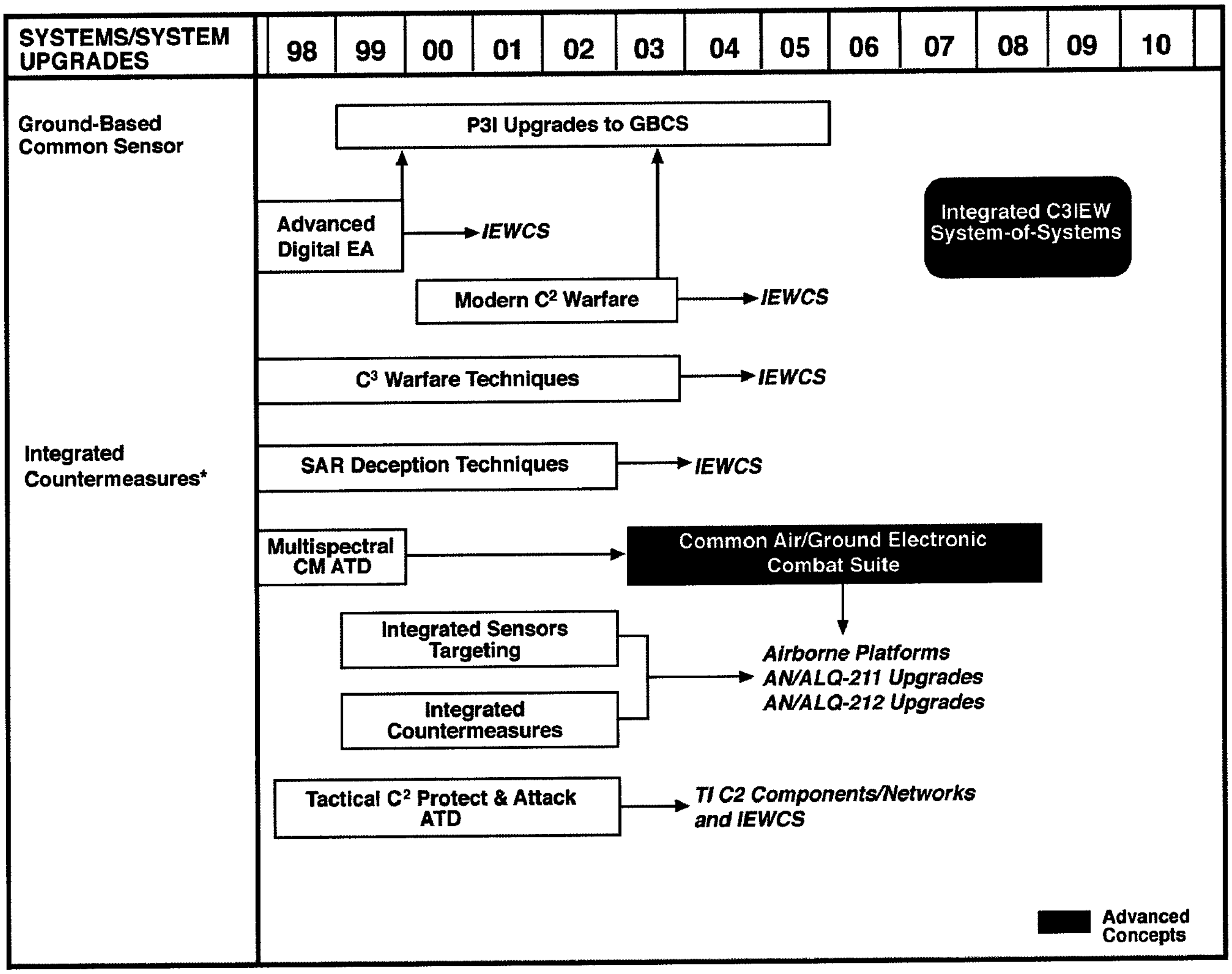
d. Technology Programs Leading to Denial Systems Modernization

Denial systems are categorized into three main areas: jamming systems, deception systems, and self-protection systems. The objective of these systems is to deny the enemy vital information and to deceive and disrupt his command and control and weapon systems. The roadmap is shown in Figure III–7.

Multispectral Countermeasures ATD (1997–99). The purpose of the Multispectral Countermeasures ATD is to develop prototype imaging IR missile jamming techniques, a fiber-optic-coupled multiline laser, and a miniature tracker as a system upgrade to the AN/ALQ–212 to protect Army helicopters from imaging surface-to-air missiles. See Section III–D "Aviation" (above) for more detailed information. *Supports:* Integrated Countermeasures, Airborne Platforms, Upgrades to AN/ALQ–211 and AN/ALQ–212, and CAGES.

Integrated Sensors and Targeting (ISAT) TD (1999–02). This program will develop a leap-ahead targeting upgrade to the suite of integrated RF countermeasures (AN/ALQ–211) and suite of integrated IR countermeasures (AN/ALQ–212). See the section on Aviation (above) for more detailed information. *Supports:* Upgrades to the AN/ALQ–211 and AN/ALQ–212, ICM, and CAGES.

Integrated Countermeasures (ICM) TD (1999–02). This program will develop and dem-



* System upgrade.

Figure III–7. Roadmap—IEW Information Denial Modernization

onstrate a leap-ahead integrated RF, EO, IR countermeasures system upgrade for the AN/ALQ–211 and AN/ALQ–212 systems for both conventional and reduced signature aircraft with HTI-to-ground survivability. See the section on Aviation (above) for more detailed information. *Supports:* Upgrades to the AN/ALQ–211 and AN/ALQ–212, ICM, and CAGES.

Tactical C² Protect ATD (1998–02). This ATD will demonstrate the ability to launch effective C² attack against integrated battlefield area communications systems (IBACSs) (threat information systems). It will also demonstrate the ability to protect the Army's tactical information systems, components, and data from modern network attacks. The demonstration will leverage existing technology, exploit modeling and simulation methods for concept exploration and definition, and use C² attack capabilities against TI information systems and components. For each C² attack method, a counter-capability (C² protect) will be incorporated. The demonstration will provide the ability to control an adversary's use of information, information-based processes, and information systems selectively through the application of offensive capabilities that deny, disrupt, or degrade operations or capabilities. *Supports:* ICM and TI C² Components and Networks.

Advanced Digital Electronic Attack (EA) TD (1995–99). This demonstration will establish

the effectiveness of exploitation and jamming techniques based on vulnerabilities of various format modern analog and digital communications systems. A prototype system for detecting and collecting analog and digital signals will be fabricated to allow for demonstration of proof-of-concept countermeasures techniques. *Supports:* IEWCS and GBCS.

Modern C^2 Warfare (2000–03). This program will demonstrate the ability to intercept, locate, and disrupt emerging high priority threat systems utilizing advanced communications technologies. This program will also investigate the advanced digital signal processing, encryption, and complex modulation techniques being incorporated into many of the commercial systems proliferating throughout the world. *Supports:* IEWCS and GBCS.

Synthetic Aperture Radar (SAR) Deception Techniques TD (1997–02). This exploratory development project will yield components to counter, through deception techniques, the SAR threat. These components include hardware, software, and associated techniques, as well as ancillary equipment. The requirements to deceive and jam air defense and surveillance radar will continue to increase as new threat radars are developed that use bistatic and other advanced techniques to avoid destruction and to counter low observables. *Supports:* IEWCS.

C^3 Warfare Techniques TD (1997–03). Provides the capability for the Army to win the information war on the battlefield or, more importantly, to affect enemy information systems prior to the actual engagement of ground forces. Modern advanced threat usable communications transmitters and receivers, both military-unique and commercial-adapted, will be technically analyzed for capabilities and vulnerabilities. Exploitation techniques will be developed and tested to counter new complex, antijam, and anti-intercept signals that continually emerge from sources throughout the world. This effort will allow the Army to counter, from an IEW perspective, the frequent technology breakthroughs that can effectively negate our ability to shape enemy actions by manipulating the flow of information and intelligence continuum of operations tasked to the force projection Army. *Supports:* IEWCS.

5. Relationship to Modernization Plan Annexes

Table III–11 shows the correlation between IEW S/SU/ACs and other AMP annexes. Note that IEW sensors provide a significant capability in the modernization process of other mission areas.

The long-term goal is for Army C^{3}IEW functions to evolve into an integrated battlespace information system (BIS–21), which provides for the information collection, management, transport, and denial functions required in the 21st century. This BIS–21 concept is synchronized with the DoD "C^{4}I for the Warrior" concept, which promotes the ability of a warfighter to "plug in" globally and obtain required battlespace information at any time.

Table III–11. Correlation Between IEW S/SU/ACs and Other AMP Annexes

System/System Upgrade/Advanced Concept		Modernization Plan Annexes: C^4	Aviation	Fire Support	Space & Missile Defense	Close Combat Light*	Mounted Forces*	Engineer & Mine Warfare	Space
System	Ground-Based Common Sensor Heavy/Light		●	●	○	●	●		
	Tactical UAV Intel Package	○	○	●	●		●		
System Upgrade	Enhanced Trackwolf	○	○	○	○				
	Advanced QUICKFIX	○	○		●				
	ASAS Upgrades	○		○	○				○
	Integrated Countermeasures		●	○			○		
	Integrated Meteorological System	●	○	○	○	○	○	○	
	Meteorological Measuring Set	○		●	○				
Advanced Concept	Integrated Intercept System	○		○	○				
	Integrated Sensor System	○		○	○		○	○	
	Distributed IEW Fusion	○		○	○	○	○		○
	Common Air/Ground Electronic Combat Suite	○	●	○			●		
	Profiler	○		●	●				

* See Combat Maneuver Annex.
● System plays a significant role in the modernization strategy
○ System makes a contribution to the modernization strategy

G. MOUNTED FORCES

The violence unleashed during Desert Storm only foreshadows our future capabilities. Lethality also comes from the ability to generate combat power—the combination of leadership, protection, maneuver, and firepower—in synchronization so that the effect is devastating.

General Carl E. Vuono
Former Army Chief of Staff

1. Introduction

The greatest S&T challenge in the mounted forces mission is to make our most capable mounted forces lighter, more lethal, and more deployable at reduced cost, so as to react to regional conflicts in the post-cold-war era better, while improving their mobility, lethality, C^4I capability, survivability, and sustainability.

Mounted forces require expanded capabilities to acquire and kill the array of threat targets in all weather, on the move, day/night, in cluttered environments, and at long ranges with increased probability of destruction out to the extent of the commander's battlespace. S&T programs must focus on warfighter needs for future systems or system upgrades. Investments are being made to apply technology horizontally across multiple combat and tactical systems.

2. Relationship to Operational Capabilities

Mounted forces SU/ACs address the progress of the Army's desired operational capabilities, as they relate to the patterns of operation shown in Table III–12. A direct correlation exists between the SU/ACs listed and the six patterns of operation.

3. Modernization Strategy

Dominate the maneuver battle is one of the Army's modernization objectives. The mounted forces section of Annex B, "Combat Maneuver," in the 1996 Army Modernization Plan annex supports this objective by providing an assessment of the mounted forces strengths and weaknesses. The annex also outlines a modernization program to correct deficiencies and exploit strengths. It calls for the following major improvements to continue our modernization program: increase target acquisition, digitize the battlefield, increase lethality, increase survivability, and improve force structure.

Six integrated concept teams (ICTs) have been formed to address solutions to user-defined requirements. For each ICT, an S&T director has been appointed. S&T directors are technology program managers chartered to oversee and integrate those relevant S&T activities. These ICTs, along with their primary focus, are as follows:

- *Abrams ICT (current fleet modernization).* S&T activities will target technology transfer to M1A2 Abrams upgrades. The insertion of required technology will be facilitated by ongoing electronic upgrades.
- *Future Scout and Cavalry System (FSCS) ICT.* This ICT developed the FSCS program with a goal of equipping the first unit in 2007. Specific attention is being given to stealth, a wide array of sensor capability, connectivity to the digitized battlefield, and survivability.
- *Future Combat System (FCS) ICT.* The FCS ICT devised a program to develop and field a leap-ahead combat program to be fielded between 2015 and 2020.
- *Suite of Survivability Enhancements System (SSES) ICT.* The SSES ICT will coordinate the development of a suite of survivability enhancements for ground combat vehicles. This technology will protect the mounted force from known enemy threats.
- *Force XXI Battle Command Brigade and Below ($FBCB^2$).* The $FBCB^2$ ICT will conduct a concept review of C^2 functions and will define required operational capabilities within Armor Center proponency for combined arms command and control (CAC^2) at brigade and below.

Table III–12. Mounted Forces System Capabilities

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
System Upgrade							Increased situational awareness	
M1A2 Abrams Soldier Enhancement Program		○	●	●	○		• Compliant with digital battlefield • Positive hostile identification	
Abrams P³I Program		○	●	●	○		• Threat warning sensors Increased target acquisition	
M2A3 Bradley	○	○	●	●	○		Increased target acquisition Increased threat detection Increased survivability	
Advanced Concept								Leap ahead lethality
Future Combat System		○	●	●	○	○		• Extended range • Indirect and direct fire modes • Rapid rearm Reduced crew size Reduced crew workload
Future Scout and Cavalry System			●	●	○	○		Improved situational awareness • Extended range sensors • Digital battlefield compliant Reduced battlefield signature Silent watch operation
Future Infantry Vehicle		○	●	●	○	○		Increased dismounted squad transportability Land warrior compatible Improved situational awareness Improved lethality

● Provides significant capability ○ Provides some capability

- *Future Infantry Vehicle (FIV).* The FIV ICT has developed a program plan to support the acquisition cycle, investigate technologies, develop S&T programs, demonstrate technology integration, and help define operational tactics. Results of the ICT will be used to field an FIV with an optimal mix of survivability, mobility, lethality, training, and C⁴I capabilities. The FIV program will support the dismounted force with a first unit equipped in the 2012 timeframe.

4. Roadmap for Mounted Forces Modernization

Table III–13 presents a summary of demonstrations and technologies. The roadmap in Figure III–8 portrays the progression of the Mounted Forces program to include TDs, ATDs, and SU/ACs.

a. Lethality Technology Demonstrators

Compact Kinetic Energy Missile (CKEM) TD (1996–99). This TD will develop a lightweight miniature (35–40 kg) hypervelocity kinetic energy (KE) missile, compatible with the line-of-sight antitank (LOSAT) target acquisition and tracking system and could be compatible with the fire control system for close combat and short-range air defense missions. It will demonstrate increased flight maneuverability against close-in airborne targets with continuous control actuation for significantly reduced minimum range and increased missile platform adaptability. Demonstration of this miniature hypervelocity missile concept will provide capability for a significant increase in lethality, survivability, and mobility of a dual-role close combat and short range air defense KE weapon system that is easily stowable on tracked combat vehicles. *Supports:* HMMWV, FCS, and FIV.

Direct Fire Lethality ATD (1996–01). This ATD will demonstrate promising technologies to enhance the hit and kill capabilities of armored vehicles while reducing O&S costs. Technologies must be explored that provide a quantum leap in performance with little or no weight/volume burden on the vehicle. Emphasis will be placed on defeat of advanced appliqué armors utilizing KE novel penetrators and axial/radial thrusters to compensate for jump errors from the ammunition launch package after muzzle exit. Technologies such as distributed direct (gearless) drives, optical fiber muzzle reference system, and modern digital servo control will be incorporated into the turret and main gun to eliminate system errors and compensate for terrain and firing disturbances experienced by ground combat vehicles during dynamic firing scenarios, thus increasing the probability of hit and kill. *Supports:* Abrams, FSCS ATD, and FCS.

Table III–13. Mounted Forces Demonstration and System Summary

Advanced Technology Demonstration	Technology Demonstration
Direct Fire Lethality	Compact Kinetic Energy Missile
Battlefield Combat Identification*	Tank Extended Range Munition
Target Acquisition	Fuze Technology
Battlespace Command and Control*	Future Combat System Armament
Multifunction Staring Sensor Suite	Advanced Light Armament for Combat Vehicles
Future Scout and Cavalry System	Full-Spectrum Active Protection
Composite Armored Vehicle	Intravehicle Electronics Suite
	Advanced Electronics for Future Combat System
	Ground Propulsion and Mobility
	Propulsion Demonstration for Future Combat System
	Future Combat System Integrated Demonstration
	Future Infantry Vehicle
	Lightweight Chassis/Turret Structures
System/System Upgrade/Advanced Concept	
System Upgrade	**Advanced Concept**
M1A2 Abrams SEP	Future Combat System
Abrams P^3I	Future Scout and Cavalry System
M2A3 Bradley	Future Infantry Vehicle

* See section on C^4 (above).

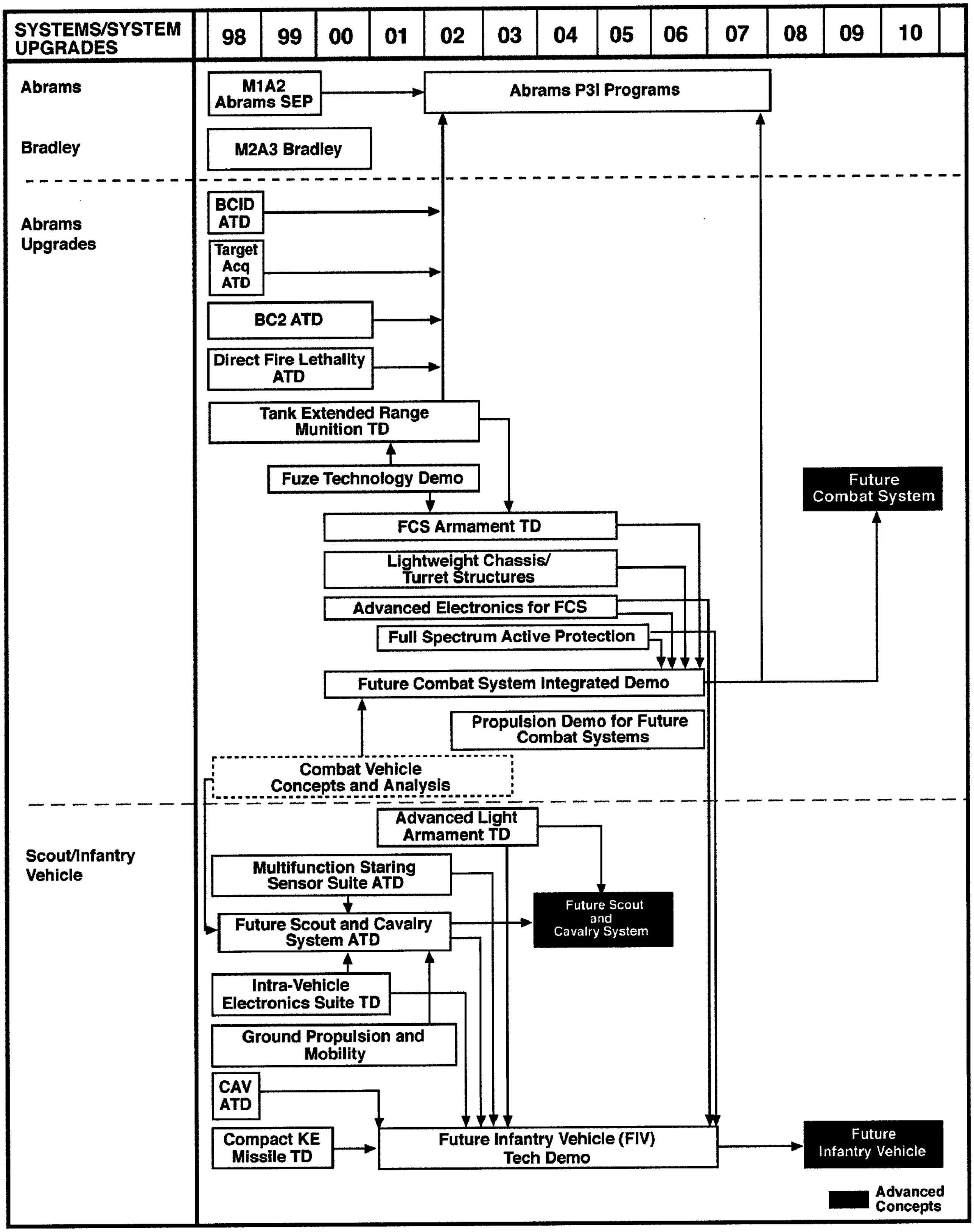


Figure III-8. Roadmap—Mounted Forces

Tank Extended Range Munitions (TERM) TD (1998–02). This TD will demonstrate a fully integrated tube-launched 120-mm precision munition for the Abrams tank capable of defeating high-value threats, advanced armor threats equipped with explosive reactive armor, or active protection systems out to 8-km line of sight and non-line of sight. TERM will demonstrate the synergy at the tactical level of targeting information available from forward observers (e.g., FSCS) through Army digitization efforts, and the lethality capability provided to the Abrams utilizing TERM. *Supports:* Abrams and FCS.

Fuze Technology TD (2000–03). This TD will demonstrate promising fuze technologies for improved performance/reliability and dramatic reduction in life-cycle cost through low unit production cost (UPC) and component applications across DoD. The TD will demonstrate low-energy electronic safe and arm (ESA) devices in a 1-cubic-inch, $50 configuration, suitable for missiles, smart and brilliant munitions. Develop and demonstrate appropriate fuze sensors for counter active protective system (APS) munitions/missiles to detect correct standoff distance from threat vehicles and the launch of active protection system countermunitions. *Supports:* Counteractive Projection System (CAPS) Fuzing—FOTT, Javelin, TOW upgrades, Abrams Sustainment, FCS, ESA–PEO Tactical Missiles, Tank Extended-Range Munitions, Sense and Destroy Armor (SADARM) upgrades, Area Denial Systems, and Remote Activation Munitions System (RAMS).

Future Combat System Armament TD (2000–04). Develop and demonstrate moderate risk armament system technologies capable of meeting the direct and indirect fire high-probability-of-kill lethality requirements of an FCS vehicle; conduct hardstand demonstration of components; and transition all hardware to the Tank–Automotive Research, Development, and Engineering Center (TARDEC) FCS integrated TD for vehicle integration activities. The FCS armament TD will demonstrate gun, ammunition, fire control, and ammunition handling technologies. *Supports:* All antiarmor weapon platforms—Abrams, FCS, KE/chemical energy (CE) Missiles, FSCS ATD, FIV, and USMC amphibious assault vehicles.

Advanced Light Armament for Combat Vehicles TD (2001–03). Leverage and integrate state-of-the-art U.S. and foreign technologies in bursting munitions, novel penetrators, and propulsion systems into mature medium-caliber ammunition configuration for application to Bradley, FSCS, and FIV. Effectiveness goals to be demonstrated will be 75–100 percent greater than standard point detonating rounds and 20–40 percent improvement over KE and foreign bursting rounds. Detailed ammunition designs will be based upon results of an Armaments Research, Development, and Engineering Center (ARDEC)/ARL technology programs. *Supports:* FIV, Bradley, FSCS, and Longbow Modernization.

b. Survivability Technology Demonstrations

Full-Spectrum Active Protection (FSAP) TD (2001–05). The objective is to deliver an integral configured active protection (AP) countermeasure for engineering and manufacturing development that provides general vehicles protection against tube-launched KE and high-explosive antitank (HEAT) munitions. FSAP will exploit, adapt, and develop/leverage technologies from tri-service, industrial, and foreign programs. FSAP will provide protection against all threats, reducing the probability of kill to 0.2. The TD is a single low-cost countermeasure for protection against large top attack, hit-to-kill ATGM, and especially tube-launched KE and HEAT threats. *Supports:* Current Fleet, Abrams, Bradley, M113, FSCS, FIV, FCS, Crusader, and Grizzly.

c. Vehicle Electronics Technology Demonstrations

Battlefield Combat Identification ATD (1993–98). This ATD focuses on fratricide reduction and is discussed in the section on C^4 (above).

Target Acquisition ATD (1995–98). This ATD will demonstrate automated wide-area search and target acquisition, prioritization, and tracking at extended ranges. Automation of these capabilities will reduce crew workload, shorten timelines to acquire targets, and as a result effectively direct fire. The ability to acquire and hand over targets automatically supports the design of a combat vehicle with fewer crew members that is more lethal and more deployable with improved situational awareness through the digitized battlefield.

The Target Acquisition ATD will be composed of a second-generation thermal imaging sensor, an MMW radar with MTI capability, a multifunctional laser (rangefinding, laser designating, and high-density profiling mode), and a day television. The sensors will be complemented by the inclusion of ATR algorithms and a high-density processor that will run the algorithms. *Supports:* FCS, FSCS, FIV, and Abrams.

Intravehicle Electronics Suite TD (1996–00). This effort will develop crew interface and vehicle architecture technologies to enable the soldier to take advantage of the data generated on the digitized battlefield. These technologies will increase in overall crew efficiency while reducing crew size. System performance will increase while the cost ratio of electronics/software upgrades for system upgrades is reduced. Significant challenges to meeting crew efficiency goals include driving a vehicle without direct vision and using nonphysical interfaces, such as voice and audio, in a combat vehicle. *Supports:* FSCS ATD, Open Systems Joint Task Force, Army C^4I Technical Architecture, FCS, FIV, Abrams, Bradley, and Crusader.

Battlespace Command and Control ATD (1997–00). This ATD will demonstrate the capability to integrate, distribute, and graphically display numerous types of digitized command and control information (e.g., terrain, position/navigation (POS/NAV), weather, intelligence to the maneuver commander). For details see the section on C^4 (above).

Multifunction Staring Sensor Suite (MFS^3) ATD (1998–01). This ATD will demonstrate a modular, reconfigurable MFS^3 that integrates multiple advanced sensor components including a staring infrared imager, a multifunction laser, and acoustic arrays. The MFS^3 will provide scout/cavalry vehicles and amphibious assault vehicles with a compact, affordable sensor suite for long-range noncooperative target identification, mortar/sniper fire location, and air defense against low signature targets. The infrared imaging system will be configured to accommodate either visible-to-mid IR or far IR FPAs. As single focal planes capable of operating across the full optical spectrum mature, these may be inserted into the assembly. The staring IR sensor will operate at high field rates to allow sniper and mortar detection in addition to the conventional target acquisition functions. Integration of a multifunction, multiwavelength laser system will incorporate ranging, range mapping, target profiling, and laser designation to support target location, target cueing, aided target identification, and target designation. The acoustic array will provide target cueing and location and will assist in automated targeting functions. *Supports:* FSCS, FIV, FCS, and USMC Advanced Amphibious Assault Vehicle.

Advanced Electronics for Future Combat System TD (2000–04). This effort will provide an integrated electronics package and crewstation technologies to the FCS integrated demonstrator. The program will transition crewstation technologies and architecture developments from Vetronics Intravehicle Electronics TD into the FCS integrated demonstration. Technologies developed under this TD support high-power electronic devices, devices that will require such power include electromagnetic gun, electromagnetic armor, and electric drive. Additional soldier–machine interface technologies that will be developed include helmet-mounted displays, head trackers, panoramic displays, cognitive decision aids, load management algorithms, and automated route planning. Testing, demonstration, and validation of the advanced architecture and crew station technologies will be performed

in a high-power electronics vehicle systems integration laboratory (VSIL) prior to integration on the FCS integrated demonstration. *Supports:* FCS, FSCS, FIV, Abrams, Bradley, and Crusader.

d. Mobility Technology Demonstrations

Ground Propulsion and Mobility TD (1997–01). Ground vehicle mobility advances for the 2001 combat vehicle fleet will be achieved through smaller and lighter systems with improved weapon stabilization, improved ride and agility, and reduced acoustic/IR signatures. These advantages will be the result of development of several advanced component systems such as band track, semiactive suspension with an active track tensioner, and electric drives. Band track will be developed for vehicles as heavy as 30 tons, providing weight savings and quiet operation. Semiactive suspension will be developed incorporating a track tensioning system that will provide improved fuel economy and better track retention. Electric drive development will center on incorporation of running gear technology such as motors and generators being developed through cooperative efforts by government agencies (Army, DARPA, DOE, USMC) and industry. *Supports:* FSCS and FIV.

Propulsion Demonstration for Future Combat Systems (2002–06). This effort will define the complete FCS propulsion configuration and will complete much of the detail design of all major components. An FCS engine will demonstrate power, fuel economy, heat rejection, and critical temperatures within 20 percent of target values. By FY06, a fully active electromechanical suspension for a future combat system weight (>40 ton) class vehicle will be demonstrated. By FY06, TARDEC will complete integrated track and suspension mobility demonstration. The Electric Drive Technology Development Hardware Demonstration Program will be funded primarily by DARPA and managed by the Army. Subsequently the DARPA program technology will transition to the Army for integration in future vehicles. *Supports:* FCS, Abrams, and Crusader.

e. Systems Integration Technology Demonstrations

Future Scout and Cavalry System (FSCS) ATD (1998–01). The FSCS ATD will demonstrate the feasibility and operational potential of an advanced lightweight vehicle chassis integrating scout-specific and advanced vehicle technologies developed in other technology-based programs. The effort will be fabricated and tested in virtual and real environments to evaluate and validate sensors/situational awareness capabilities and to develop scout tactics.

The FSCS ATD will develop and demonstrate scout-specific mobility components such as electric drive, semi-active and fully active suspension, and band track. Other specific technologies that may be integrated into the scout platform include MFS^3, advanced lightweight structural materials and armors, advanced crew stations, advanced C^2, medium-caliber weapon, and advanced survivability systems. This effort will validate the inherent signature reduction of advanced mobility technologies. The FSCS ATD will fast track in FY02 to the EMD phase of the FSCS program. *Supports:* FSCS, FIV, and FCS.

Future Combat System (FCS) Integrated TD (2000–06). This effort will demonstrate the maturity of the FCS candidate's revolutionary technologies in the vehicle configuration required for operation in the *Army After Next*. Leap-ahead lethality in vehicles 50 percent lighter is required to employ strategic mobility throughout the AAN vision. Critical issues to be addressed are the acceptance of two-crew-vehicle operation, leap-ahead mobility (60 mph cross country), nontraditional survivability (replacing ballistic protection with signature management, countermeasures, and active protection), and indefensible lethality (both direct and indirect fire). Virtual prototypes will be constructed and evaluated, and a system integration laboratory (SIL) will be implemented with laboratory hardware to validate electronics integration. *Supports:* FCS, FIV, and FCS ICT.

Future Infantry Vehicle (FIV) TD (2001–06). This effort will demonstrate, in both real and virtual environments, the feasibility and operational potential of a FIV by integrating FIV-specific technologies with complementary advanced vehicle technologies. Requirements to be achieved in the FIV are increasing the crew capabilities through automation and crew enabling remote stations for vision as well as armament and vehicle operation. Survivability will be increased by 33–50 percent using a combination of improved armor protection, hit avoidance, and signature management. On-board training/battle rehearsal will increase 100 percent by eliminating technical manuals, having on-board simulators and embedded training. All systems' advanced diagnostics/prognostics will be demonstrated. Full dismount squad size will increase from 7 to 11. Mobility will be improved to be equal to the FCS. Lethality will be improved through the integration of an advanced medium caliber weapon, fire-and-forget FOTT P^{3}I missile system and the addition of nonlethal devices. *Supports:* M2/M3 Bradley upgrades, FSCS EMD, FIV EMD, and the combined arms medium class of vehicles.

f. Vehicle Chassis/Turret Structures Technology Demonstrations

Composite Armored Vehicle (CAV) ATD (1994–98). The CAV ATD will demonstrate the feasibility of producing lighter weight ground combat vehicles manufactured from advanced composites. The CAV ATD will consist of an integrated demonstration of advanced composites and advanced lightweight armors on a C–130 air-deployable 22-ton vehicle emphasizing manufacturability, repairability, nondestructive testing, and structural integrity. The vehicle structure and armor will weigh at least 33 percent less than comparable steel or aluminum. CAV's operational advantages will improve survivability through inherent signature reduction of composite materials on vehicle shaping, and improve agility and deployability by reducing structure and armor weight. *Supports:* Crusader EMD, FSCS, FCS Demonstrations, and FIV.

Lightweight Chassis/Turret Structures TD (2000–04). This TD will develop and demonstrate a minimum weight structural designs vehicle chassis and turret to achieve the future combat system 40-ton gross vehicle weight. Modular, removable armor for in-country installation will be incorporated. Two hull and turret structures will be built, one for firing and one for the FCS integrated demonstration. *Supports:* FCS, High Mobility Rocket System (HIMARS), Future Engineer Systems, and *Army After Next* fleet.

5. Relationship to Modernization Plan Annexes

Table III–14 exhibits the cross-fertilization that exists between SU/ACs and several AMP annexes. All of the SU/ACs, ATDs, and TDs presented in this section support the Army Mounted Forces modernization areas, and many of them support additional modernization areas.

Table III–14. Correlation Between Mounted Forces S/SU/ACs and Other AMP Annexes

System/System Upgrade/Advanced Concept		Modernization Plan Annexes: Fire Support	Close Combat Light*	IEW	C^4
System Upgrade	M1A2 Abrams SEP	○		○	●
	Abrams P^3I	○		○	●
	M2A3 Bradley	○	●	○	●
Advanced Concept	Future Combat System	●		●	●
	Future Scout and Cavalry System	●	○	○	●
	Future Infantry Vehicle	●	●	●	●

* See Combat Maneuver Annex.
● System plays a significant role in the modernization strategy
○ System makes a contribution to the modernization strategy

H. CLOSE COMBAT LIGHT

Those experimenting today will lead modernized units tomorrow.

Togo D. West, Jr.
Secretary of the Army

1. Introduction

In light of the changing threat, the Army is placing increased emphasis on developing a more flexible, combat-ready military force that can respond quickly to any crisis situation and that is capable of deterring aggression and, should deterrence fail, defeating the enemy throughout the operational continuum. The cornerstone of this flexible force is the Army's light forces. The light forces comprise combat, combat support, and combat service support units that participate in and support the close battle. Their mission is to defeat threat forces in a low-intensity conflict, while retaining a capability for employment in mid- to high-intensity conflicts and OOTW.

Light forces, as well as all other elements of future land combat forces, must be highly deployable, able to execute missions outside the operational envelope of opposing forces, and survive against myriad lethal antiarmor weapons and other nontraditional, nonlethal weapons. Light forces are the option of choice for peacetime engagement and conflict prevention. They must show the advantage of new technologies and field equipment that is more lethal, survivable, maintainable, smaller, lighter weight, and easily transportable.

2. Relationship to Operational Capabilities

It may be necessary for light forces to conduct military operations under a variety of conditions generated by a wide range of threats. We must, therefore, continue to leverage technology in the following key areas to ensure our capabilities exceed those of our current and potential threats:

- Integrate digitization.
- Provide smaller, lighter, precision firepower.
- Facilitate mobility and maneuver.
- Maximize leadership and training.
- Increase protection.

A major Army initiative, designed and geared toward achieving U.S. light forces superiority, is the RFPI ACTD. This ACTD explores new tactics and technologies via a system-of-systems approach providing a path to an air-deployable, early entry light force that is significantly more capable of destroying a heavy armored threat beyond traditional direct fire weapons range. The RFPI concept includes a variety of advanced sensors (air and ground, manned and unmanned); several precision-guided, non-line-of-sight weapons; responsive command and control mechanisms; and automated targeting. Target handover will be facilitated by tactical digital data transfer systems now being developed as part of the U.S. ABCS program. Specifically, this ACTD will provide the opportunity to explore the integration of new technologies with modified tactics, technologies, and procedures to improve the survivability of our early entry forces.

The light forces are key elements of the U.S. forward-deployed, crisis-response, and reinforcing forces. Light forces provide versatility in two ways: they are rapidly deployable and they are most suited for fighting in close terrain. These characteristics enable light forces to be used in all of the Army's roles and missions. Some examples of these are:

- *Initial forward deployment and the timely reinforcement of forces.* This has deterrent value and sends a message of resolve in a crisis situation, yet is not perceived as escalatory.
- *Contingency crisis situations,* where a rapid and decisive deployment can forestall or limit hostilities. In an area where no infrastructure exists, a forced entry and subse-

quent rapid build-up of force may be required.

- *Nation building/military operations other than war.* Nations involved in low-intensity conflicts may require economic and social-political solutions. Light forces are ideally suited for the role of providing security and promoting the political and social development of nations. Their inherent characteristic of low equipment density does not create an impact on a developing country, yet it provides a widespread sense of security.
- *Counterterrorism* can be used both domestically and internationally. It may require special nontraditional methods.

Table III–15 represents close combat light S/SU/ACs capabilities and their relationship to the Army modernization objectives. This table also provides highlights of capabilities provided by other Army modernization programs discussed in detail throughout this chapter.

3. Modernization Strategy

The Combat Maneuver annex to the AMP, of which close combat light is a part, reviews the requirements placed on the light forces over the entire spectrum of potential future conflicts and is the Army's strategy for modernization of its strategically flexible light forces. The close combat light modernization strategy focuses on new materiel that increases lethality, mobility, and survivability while correcting deficiencies and providing the necessary "tailorability" across the spectrum of conflict. Priority is given to equipment that significantly increases flexibility and survivability.

Early entry forces will gain increased lethality and survivability against heavy forces through application of the hunter–standoff–killer concept—use of advanced forward sensors (hunters) and standoff weapons (killers) that will be demonstrated in a system-of-systems engaging enemy forces at ranges beyond their ability to counter.

Close combat light extracts those portions of all other modernization plans and mission areas that are applicable to light forces, examines them from the perspective of the light forces roles and missions, and ensures that the light forces are provided adequate resources.

This plan is the result of a thorough examination of the threat, the nature and imperatives of the future battlefield, a recognition of the need to reduce significantly the time required to develop and field advanced technology systems, and the recognition of time-constrained resources. The plan uses technology and systems that will make a significant contribution to the deterrent value of light forces or provide leap-ahead capabilities. The objective is to ensure that the Army light forces meet the future battlefield requirements of increased firepower, flexibility, mobility, survivability, and sustainability.

4. Roadmaps for Close Combat Light

Table III–16 is a summary of close combat light demonstrations and systems.

Because close combat light is primarily an integration plan, the applicable S/SU/ACs, along with the majority of appropriate ATDs and TDs that provide capabilities to the close combat light mission, are shown on the existing roadmaps throughout the rest of Chapter III and are not repeated here.

The RFPI, however, is unique to close combat light and is displayed in Figure III–9. It depicts the Army ATDs and technology demonstrations that support the RFPI ACTD in the form of capabilities provided by systems or system upgrades.

In addition to the RFPI demonstrations, there are other technology demonstrations that are unique to the close combat light mission. These are shown in the roadmap on Figure III–10.

Table III–15. Close Combat Light System Capabilities

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
AVIATION							Light attack/armed reconnaissance Day/night and adverse weather Antiarmor/air to air Automatic target recognition Advanced survivability Self deployability	Ground maintenance associate Increased payload Advanced transmission Man-machine interface Increased lethality All-weather NOE pilotage Multirole/versatility Automatic target recognition Signature control Advanced maneuverability/agility Advanced propulsion Integrated flight/fire control Precision navigation NOE sling load operations
System								
RAH–66 Comanche	○	●	●	●	●	○		
System Upgrade								
AH–64D Apache Longbow	○	●	●	●	●	○		
Advanced Concept								
Improved Cargo Helicopter	●	●		○	○	●		
Enhanced AH–64D Apache	○	●	●	●	●	○		
Joint Transport Rotorcraft	●	●		○	○	○		
MULE	●	○		○				
MRMAAV		○		●	○			
C⁴							Distributed processing and databases Integrated system management Gateways and multilevel security Jam resistant capability High mobility and survivability Expert system planning aids Battlefield visualization Assured communications	Enhanced situation awareness Synchronized battle management Voice input/output Seamless, transparent communication Secure multimedia Automated network management C^2 on the move Integrated sensor weapon C^3
System Upgrade								
Communications—Wide, Local, Mobile	●	●	●	●	●	●		
Advanced Concept								
Force XXI/Vision 2010	●	●	●	●	●	●		

Table III–15. Close Combat Light System Capabilities (continued)

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
INTELLIGENCE & ELECTRONIC WARFARE							Manpack/vehicle for surveillance/targeting Penetration and standoff IEW Automated terrain identifier ELINT, COMINT, and EA radar multisensor package Automated weather decision aids Man-portable sensor to detect, track, and classify vehicle and personnel	Integrated system of sensors and collectors • Multispectral • Advanced processing Information dissemination • Multiechelon • Closed-loop target hand-over Intelligence analysis and assessment
System								
Ground-Based Common Sensor—Light*		○	●	○	○			
UAV Tactical Intelligence Package		○	●	○	○			
System Upgrade								
Integrated Meteorological System	○	○	●	○	○			
Meteorological Measuring Set	○	○	●	○	○			
Advanced QUICKFIX		○	●	○	○			
ASAS		○	●	●	○			
Advanced Concept								
Distributed IEW Fusion		○	●	●	○			
Profiler	○	○	●	○	○			
CLOSE COMBAT LIGHT							Dismounted infantry combat power Increased capability of vehicle-mounted support weapons Increased self-protection Higher altitude personnel parachute opening capabilities Improved glide ratio for personnel parachutes Lower ground impact velocities for airborne soldiers	Increased payload Increased lethality Enhanced situation awareness Integrated system of sensors Improved probability of hit IR/TV sensor Lightweight Ability to accurately deliver supplies/equipment from offset distances Increased delivery accuracy Covert, day/night, and limited visibility airdrop capability
System								
Objective Crew-Served Weapon		●		●	●	○		
Objective Sniper Weapon		●		●	●	○		
System Upgrade								
Advanced Precision Airborne Delivery System	●	●		●	●	●		
Advanced Personnel Airdrop Technologies	●	○		○				
Advanced Concept								
Precision Offset High Glide Aerial Delivery of Munitions and Equipment	●	●		●	●	●		

Table III–15. Close Combat Light System Capabilities (continued)

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
SOLDIER							Optimal food mix—quality and amount Improved soldier and crew protection Improved accuracy, effects, and logistics Battery unit/engine fuel cells, lightweight power source Thermal weapon sight to detect man-sized targets Soldier computer Increased accuracy, probability of hit, and range Lightweight system	System weight reduction Minimization of system power Life-cycle cost reduction Improved system fightability
System								
Objective Family of Small Arms		●			○	○		
Land Warrior	○	●	●	○	○	○		
Objective Sniper Weapon		●		○	○	○		
System Upgrade								
Force XXI Land Warrior	○	●	●	○	○	○		
Army Field Feeding Future	○					●		
Objective Individual Combat Weapon		●		○	○	○		
Objective Crew-Served Weapon		●		○	○	○		
NCB							Decontamination downtime reduced Detection and ID of all CB threat agents Low bulk, low-cost CB protective mask Multispectral smoke material to defeat enemy RSTA assets Defeat or degrade enemy armored targets Improve entry/exit	Defeat/immobilize enemy threat equipment (i.e., trucks, tanks) Close-in fire support for SOF and MOUT Increased first-kill capability of hardened targets Large area defeat of enemy threat equipment Counter-counter battery Target marking
System/ System Upgrade/ Advanced Concept								
Individual Protection	○	●				○		
Collective Protection	○	●				○		
Chemical Detectors		●	○		○			
Biological Detectors		●	○		○			
Smoke/Obscurants		●	○	○	○			
Decontamination	○	●				○		
AIR DEFENSE								IR counter-countermeasures Improved lethality against helicopters 360-degree coverage
System Upgrade								
Patriot Advanced Capability (PAC3)	○	●	●	○	○			
Bradley Stinger Fighting Vehicle	○	●	●	○	○			
Advanced Concept								
Stinger Block II	○	●	●	○	○			

Table III–15. Close Combat Light System Capabilities (continued)

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
ENGINEER AND MINE WARFARE							Advanced staring FPA Advanced sensors Lightweight airborne standoff detection Advanced ATR Neutralized antitank mines Detection avoidance Counter threat thermal IR sensors Integrated, cooperative, controllable two-way minefield Detect mines with large lethal radii	
System								
Lightweight Airborne Multispectral CM Detector		●	●	○	○			
Ground Standoff Mine Detection		●	●	○	○			
System Upgrade								
Mine Hunter–Killer		●	●	○	○			
Low-Cost, Low-Observable Technologies		●		●	○			
Digital Topographic Support System/Quick Response Multicolor Printer	○	○	●	○	●	○		
FIRE SUPPORT							Improved range, agility, and RAM Extended range kill Increased sensor accuracy Decision aids Smart weapons 155-mm range from a lightweight system	Mobile long-range capability Improved targeting Precision guidance capability Lightweight, deployable, long range Increased lethality and accuracy Reduced fire mission duration Reduced logistic burden
System								
Crusader	●	●	○	○	○	○		
Lightweight 155-mm Towed Howitzer	●	●		○	○	○		
System Upgrade								
Firefinder P^3I		○	○					
Multimode Airframe Technology	○	●		●	●	○		
Extended Range Artillery (ERA) Projectile—XM982	●	●		●	●	○		
Advanced Concept								
Precision Guided Mortar Munition	●	●		●	●	○		
Guided Multiple Launch Rocket System	○	●		○	○	○		

Table III–15. Close Combat Light System Capabilities (continued)

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
LOGISTICS							Shelf-stable ration components	Accurate delivery of supplies/equipment from offset distances
System Upgrade							Enhanced rations performance and flexibility	Increased delivery accuracy via an autonomous GPS-based guidance and navigation system
Aerial Delivery	●	○		●	●	●	Reduced manpower	Covert day/night and limited visibility airdrop capabilities
Army Field Feeding Future	○	○				●	Improved quality of life	
Rapid Deployable Food Service for Force Projection	○	○				●	Improved precision-guided delivery of munitions	
ReformD/Emergency Petroleum Quality	●						Improved morale	
Electric Power Generation	○					●	Improved food, nutrition, and readiness	
Munitions Survivability	○	●				●	Lower O&S costs	
Advanced Concept								
Precision Offset, High-Glide Aerial Delivery	●	○		●	○	●		
Containerized Kitchen	○	○				●		
TRAINING							Joint services training	
System Upgrade							Component training strategies	
Distributed Interactive Simulation	●	●	●	●	●	●	Combined arms training	
Combined Arms Training Strategy	○	●	●	●	●	○	Battle command training	
Combat Training Centers	●	●	●	●	●	●	Upgrade of multiple integrated laser engagement system equipment	
Nonsystem Training Devices	●	●	●	●	●	●	Synthetic battlefield	
Range Instrumentation Targetry Devices		○	●	●	●		Special operations training	
Combined Arms Tactical Trainer	●	○	●	●	●	●	Contingency mission training	
Advanced Concept							Range modernization	Joint mission training
Distributed Models/ Simulation for Joint/ Theater Exercises	●	●	●	●	●	●		Mission rehearsal
Innovative Simulation-Based Training Strategies	●	●	●	●	●	●		Mission readiness estimation
Advanced Assessment Technologies	●	●	●	●	●	●		Behaviorally accurate semiautomated forces

Table III–15. Close Combat Light System Capabilities (continued)

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
SPACE							Real-time warning to theater forces	
System							Pager warning to troops	
Joint Tactical Ground Station	●	●	●	○	●	●		
Eagle Vision II	●	●	●	○	●	●		
Surveillance Targeting and Reconnaissance Satellite	●	●	●	○	●	●		
System Upgrade							DBC terminal upgrades	
SCAMP Terminals	●	○	●	●	●	○	SATCOM paging Improved situational awareness	
Tactical Exploitation of National Capabilities	●	○	●	●	●	○	Improved targeting Improved pointing accuracy	
Advanced Concept								SATCOM on the move
Communications Transport	●	○	●	●	○	○		High-capacity voice/data/video transmission
Advanced Image Collection and Processing	○	○	●	●	○	○		
MOUNTED FORCES								Leap-ahead lethality
System Upgrade								Hypermobility
M1A2 Abrams SEP		○	●	●	●	○		Reduced crew size and workload
Abrams P^{3}I		○	●	●	●	○		Situational awareness
M2A3 Bradley	○	○	●	●	●	○		Silent watch operation
Advanced Concept								Increased squad size
Future Combat System	●	○	●	●	●	○		Improved lethality
Future Scout and Cavalry System		○	●	●	●	○		
Future Infantry Vehicle	○	○	●	●	●	○		

Table III–15. Close Combat Light System Capabilities (continued)

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
COMBAT HEALTH SUPPORT							Protection against blood and tissue stages of malaria Protection against *Shigella* Forward diagnostic test kits Protective vaccines against encephalomyelitis, botulium toxin, staphylococcal enterotoxin (SEB), anthrax, plague, Brucella, and ricin Improve blood storage duration Localize antibiotic administration Enhance monitoring and diagnosis far-forward Performance-enhancing nutritional supplements Reduction and prevention of deployment stress	Protection against malaria using a combined vaccine Combined oral vaccine for protection against diarrheal disease CAD, molecular fingerprinting-, and molecular biology-based drug discovery Multiagent protection with single vaccination Medical diagnostics and communications for casualty care enhancements Performance optimization Sleep and alertness enhancement Physiological models
System/System Upgrade/Advanced Concept								
Infectious Diseases of Military Importance	●	●	○					
Medical Chemical and Biological Defense	○	●						
Combat Casualty Care	●	●	○			○		
Army Operational Medicine	●	●	○			○		

● Provides significant capability ○ Provides some capability * Contains communication jamming capability

Table III–16. Close Combat Light Demonstration and System Summary

Advanced Technology Demonstration	Technology Demonstration
Precision Guided Mortar Munition Guided MLRS (see Fire Support) Enhanced Fiber-Optic Guided Missile **Advanced Concept Technology Demonstration** Rapid Force Projection Initiative (For additional information, see Volume II, Annex B.)	**RFPI Demonstration** Aerial Scout Sensor Integration Integrated Acoustic System Future Missile Technology Integration High Mobility Rocket System 155-mm Automated Howitzer (see Fire Support) Multimode Airframe (see Fire Support) **CCL Unique Demonstrations** Objective Crew-Served Weapon Counter Active Projection System Precision Offset, High Glide Aerial Delivery of Munitions and Equipment Objective Sniper Weapon Advanced Personnel Airdrop (see Soldier) Advanced Cargo Airdrop (see Logistics) ATR for Weapons (see Aviation)

System/System Upgrade/Advanced Concept

System	System Upgrade
Objective Crew-Served Weapon Objective Sniper Weapon	Advanced Precision Airborne Delivery System Advanced Personnel Airdrop Technologies **Advanced Concept** Precision Offset, High Glide Aerial Delivery of Munitions and Equipment

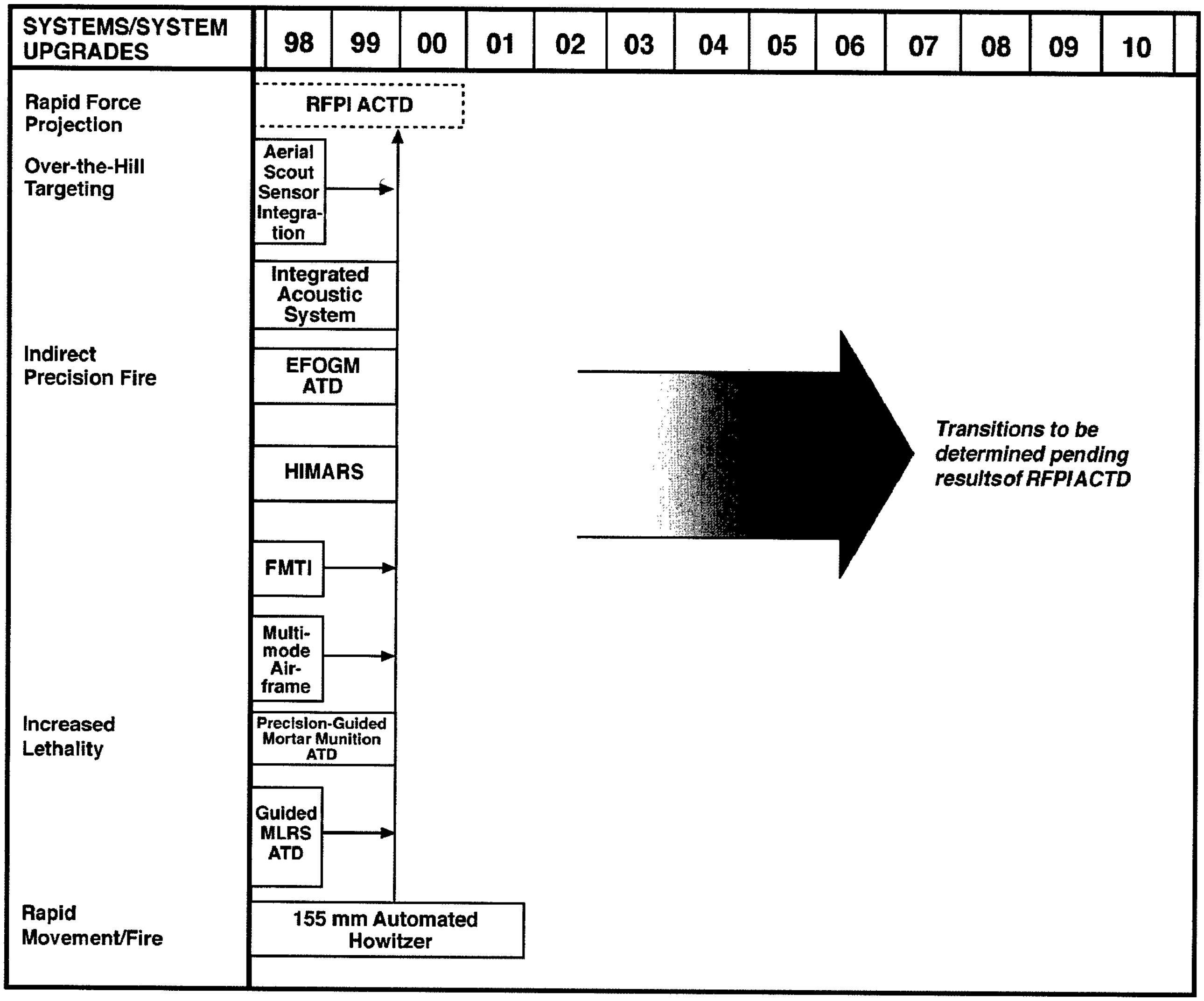


Figure III–9. Roadmap—Close Combat Light for Rapid Force Projection Initiative ACTD

a. RFPI Advanced Concept Technology Demonstration

RFPI ACTD (1995–00). The RFPI ACTD will demonstrate a highly lethal, survivable, and rapidly air-deployable enhancement to the early entry task force. This enhancement will provide automated target transfer from forward sensors to an indirect-fire weapon system with the capability to engage high-value targets beyond traditional direct-fire ranges. The ACTD provides an opportunity for extensive user interaction with the new RFPI hunter–standoff killer concept and its emerging technologies. A selected light, air assault, or airborne unit from forces command (FORSCOM) will demonstrate the RFPI ACTD concept, and will retain selected equipment for at least a 2-year extended demonstration period to provide residual capabilities and allow arrangements for long-term retention. The ACTD leverages maturing RFPI sensor technologies and an advanced command and control element. The ACTD includes automated fire control system (FCS) for selected howitzers, EFOGM non-line-of-sight weapon system, and HIMARS. It encourages user exploration of a variety of baseline procedures to optimize utility of the new hunter–standoff killer concept. *Supports:* RFPI.

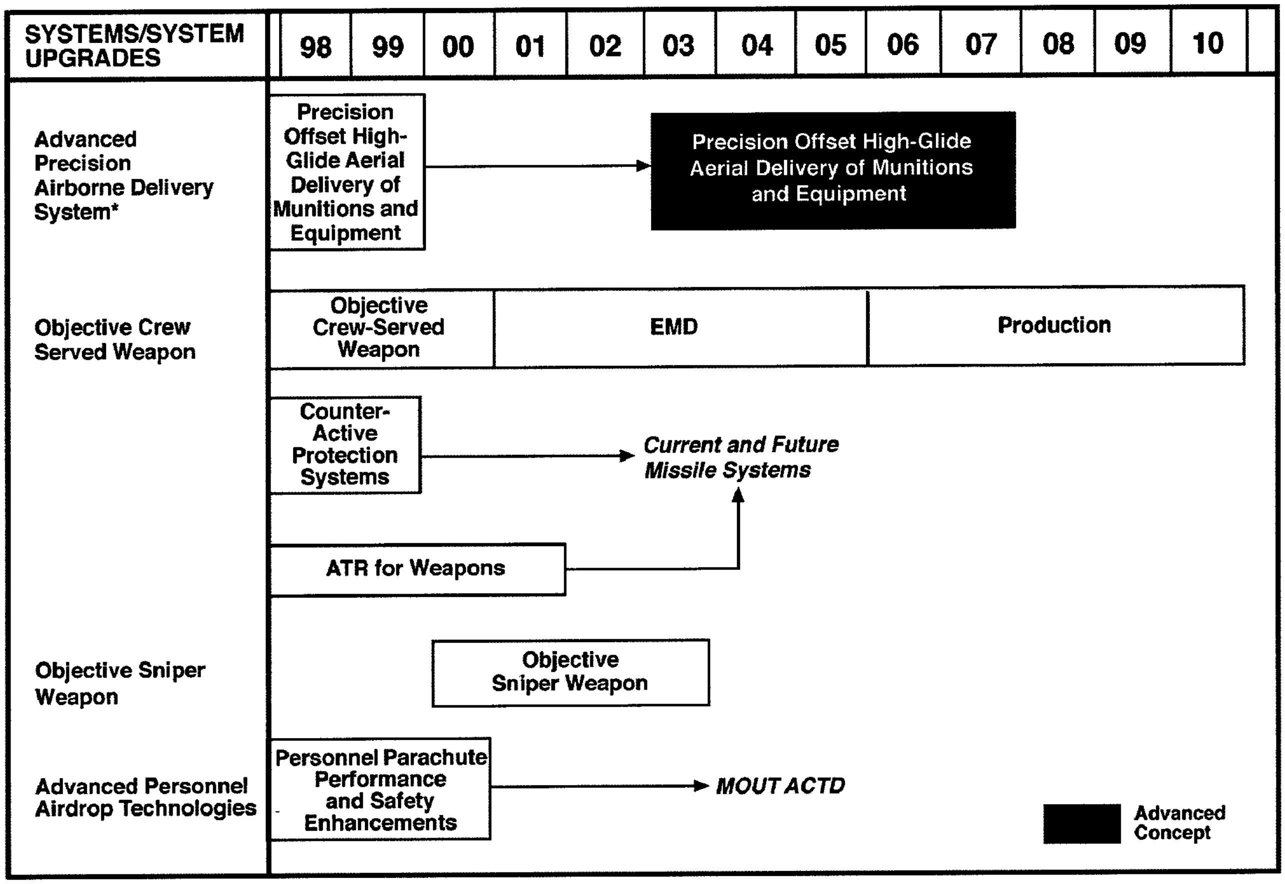


Figure III–10. Roadmap—Demonstrations Unique to Close Combat Light

b. RFPI Sensor Demonstrations

Aerial Scout Sensor Integration TD (1995–98). This TD will demonstrate technology to provide light forces with accurate, timely, "over-the-hill" reconnaissance, surveillance, and battle damage assessment capability through use of aerial sensors enhanced with ATR and smart workstation technologies. A variety of imaging sensors will be used on a surrogate aerial platform as well as a ground-based image exploitation workstation. Candidate sensors include FLIR, IR line scanner, day TV, and MTI radar. The goal is to demonstrate a reduction in data timelines, from tasking to output of tactical information. *Supports:* RFPI ACTD.

Integrated Acoustic System (IAS) TD (1996–99). This TD will demonstrate acoustic sensor technology in both hand-emplaced and air-droppable variants. Advanced acoustic sensor efforts from the Intelligent Minefield ATD (completed in FY97; see the section on Technology Transition Strategy (above), which will provide the hand-emplaced system. The air-deployable acoustic sensor (ADAS) system will be developed to provide a helicopter-deployable variant. Both systems will be demonstrated during the RFPI ACTD large-scale field experiment. *Supports:* RFPI ACTD.

c. RFPI Weapons Demonstrations

The RFPI large-scale field experiment includes several advanced concepts that will demonstrate the system-of-systems concept of hunters and standoff killers. During this timeframe, the newly configured and upgraded EFOGM, HIMARS, and 155-mm automated howitzer (with automated fire control system) will be demonstrated. Other new hunter or killer

technologies will be considered during this phase.

Enhanced Fiber-Optic Guided Missile (EFOGM) ATD (1994–99). This ATD will develop and demonstrate a remotely directed (fiber optically guided) missile system (EFOGM), modified with an imaging IR (I^2R) seeker, inertial navigational system, and other datalink modifications. It will defeat armor out to ranges of 15 km and permit the operator, through a fiber-optic guidance link to the missile seeker, to search for targets in the extended close battle area. The system has the unique ability to operate from defilade and to engage targets that are also in defilade. Friendly target recognition capability and fratricide avoidance is enhanced with a gunner operator in the loop. The EFOGM ATD will provide the advanced, non-line-of-sight weapon to be demonstrated under the RFPI ACTD. This ACTD will integrate light force organic weapons, the EFOGM, RFPI sensors, other RFPI standoff killers, and C^2. *Supports:* RFPI and JPSD Precision/ Rapid Counter MRL ACTDs.

155-mm Automated Howitzer TD (1994–00). The program will develop an advanced digital fire control system for towed artillery. See Section III–N "Fire Support" for more detailed information. *Supports:* RFPI ACTD.

Precision-Guided Mortar Munition (PGMM) ATD (1994–01). The ATD will demonstrate, through live fire and simulation, the ability of a guided mortar munition to defeat armored as well as high-value point targets. It will also demonstrate longer range, more accurate and more timely response to requests for fire through the integration of a lightweight fire control system. As part of the RFPI, the PGMM and fire control will be an advanced concept standoff killer in the RFPI ACTD. The ATD program consists of a 120-mm PGMM capable of finding and defeating enemy armor and other high-priority targets in an autonomous role, and a lightweight fire control to improve the accuracy and response time of fielded mortar systems. An initial test bed is being integrated on a HMMWV, with a follow-on effort to reduce the size and weight of the components. The program will focus on the azimuth reference unit and the software required to integrate the components completely and fire a PGMM against moving targets. *Supports:* RFPI ACTD.

Guided MLRS ATD (1995–98). This ATD is discussed in detail in the section on Fire Support.

High Mobility Artillery Rocket System (HIMARS) TD (1995–99). The HIMARS TD will provide a lightweight, C–130 transportable version of the M–270 multiple launch rocket system (MLRS) launcher. Mounted on a 5-ton family of medium tactical vehicles (FMTV) truck chassis, it will fire any rocket or missile in the MLRS family of munitions. The HIMARS uses the same command, control, and communications, as well as the same crew, as the MLRS launcher but carries only one rocket or missile pod. It will roll on and off a C–130 transport aircraft and, when carried with a combat load, will be ready to operate within minutes of landing. *Supports:* RFPI ACTD and MLRS Family of Munitions.

Future Missile Technology Integration (FMTI) TD (1994–98). This technology demonstration is discussed in detail in Section III–D "Aviation" (above).

Multimode Airframe Technology (MAT) TD (1995–98). This technology demonstration is discussed in detail in Section III–N "Fire Support."

d. Close Combat Light Unique Demonstrations

The Objective Crew-Served Weapon TD (1996–01). This TD is part of the objective family of Small Arms described in the section on Soldier and is unique to the Close Combat Light section. It will support the two-man, crew-served weapon outlined in the *Army Small Arms Master Plan* and the *Joint Service Small Arms Master Plan.* This demonstration will establish the feasibility of a lightweight, two-man portable, crew-served weapon system with a high probability of incapacitation and suppression out to 2,000 meters against protected personnel targets. It will also

have a high potential to damage light vehicles, lightly armored vehicles, water craft, and slow moving aircraft beyond 1,000 meters. The fire control system will include a laser rangefinder, environmental sensors, ballistic computer, day and night channel, and adjusted aimpoint to provide the full ballistic solution. The weapon will fire bursting ammunition to provide decisively violent target effects to overmatch threat systems and will have the ability to defeat defilade or non-line-of-sight personnel targets. The fire control system will be modular in design, eliminate the need to estimate range, provide a full solution aimpoint, and include embedded training. This weapon would be utilized by mounted and dismounted combat soldiers. *Supports:* Objective Crew-Served Weapon.

Precision Offset, High-Glide Aerial Delivery of Munitions and Equipment TD (1994–99). This TD will demonstrate revolutionary technologies for the reliable precision-guided delivery of combat essential munitions and equipment using high glide wing technology and incorporating a low cost, modular GPS guidance and control system. This technology will provide a 6:1 or better glide ratio. A modular GPS guidance package was developed and a precision high-glide capability of 500-pound payload using semirigid wing technology was demonstrated in FY96. By the end of FY99, the effort will demonstrate precision high glide of a 2,000-pound payload, with a goal of a 5,000-pound payload, using an advanced guidance package and high glide wing. An optional glide augmentation system will also be demonstrated, providing an offset range of 75 to 300 km. High-glide wing technology will significantly enhance the military aerial delivery capability through substantially higher glide ratios than are possible with ram air parachutes, and will directly benefit the initial deployment of Early Entry Forces. *Supports:* Depth and Simultaneous Attack (DSA), Maneuver Support Battle Laboratories, and Advanced Precision Airborne Delivery System.

Advanced Personnel Airdrop TD (1998–00). This effort will demonstrate improved performance characteristics and enhanced safety of existing personnel parachute capabilities. Details can be found in Section III–I, "Soldier." *Supports:* Airborne Insertion for Operations in Urban Terrain and the Advanced Tactical Parachute System development effort.

Advanced Cargo Airdrop TD (1998–00). Technologies to provide an improved cargo airdrop capability will be demonstrated. Details can be found in Section III–O, "Logistics." *Supports:* Aerial Delivery and Mobility Requirements.

Counter Active Protection Systems (CAPS) TD (1996–99). The CAPS TD will develop and demonstrate technologies/methods that can be applied to antitank guided weapons (ATGWs) for improving effectiveness against threat armor equipped with APSs.

Current technology development is concentrated in the following three areas:

- RF countermeasure (RFCM) technology for jamming or deceiving APS sensors used for detection, acquisition, and tracking.
- Long standoff warheads for shooting from beyond the range of APS fragment-producing countermunitions.
- Ballistic hardening of ATGW to reduce vulnerability to fragment impact.

Supports: Close Combat Antiarmor Weapon System (CCAWS), Advanced Missile System–Heavy (AMS–H), Javelin, and BAT.

Automated Target Recognition for Weapons TD (1998–01). This technology demonstration is discussed in detail in Section III–D "Aviation" (above).

Objective Sniper Weapon (OSW) TD (2000–02). The OSW will develop and demonstrate a single, lightweight ($\leqq$20 pounds), long-range (to 2,000 m) sniper weapon system providing very high incapacitation probabilities ($P_i > 0.5$) and materiel destruction against personnel protected by body armor or in fortifications and light vehicles, vessels, and high-value

materiel. It will demonstrate the ability to achieve objective sniper weapon goals through simulation and analyses, followed by experimentation of critical component technologies. Technical, safety, and troop testing will be conducted to demonstrate operational utility and technical maturity. *Supports:* Objective Sniper Weapon, U.S. Army Infantry School (USAIS), USMC, and Special Operations Command (SOCOM).

I. SOLDIER

Our warfighting edge is the combined effect of quality people, trained to razor sharpness, outfitted with modern equipment, led by tough competent leaders, structured into appropriate forces and employed according to up-to-date doctrine . . . I am certain the most important factor is the soldier.

General Gordon Sullivan
Former Army Chief of Staff

1. Introduction

The Army soldier modernization effort is a comprehensive, multifaceted program designed to maximize the operational capabilities of the soldier as a "battlefield system" capable of executing a full range of military operations by enhancing command and control, lethality, survivability, sustainability, and mobility. The soldier system is generically defined as the individual soldier and everything he/she wears, consumes, or carries for individual use in a tactical environment.

Over the past several years, the systems approach to modernizing the soldier has been implemented and demonstrated very successfully. The current thrust is focused on optimizing the soldier's effectiveness through (1) the synergy that results from effective integration of technologies at the systems level; and (2) the proper integration of soldier systems across a diverse spectrum of operations. Using the approach and the focus mentioned, the basis of the future human platform has a firm foundation, wherein the soldier is the focal point of a revolutionary vision. In this vision, technology is driven and designed around the "human element," knowing that each soldier is different. However, all must perform the mission or task adequately, as required by doctrine, regardless of size and gender.

To date, the soldier's effectiveness has increased and will continue to improve at a rate that is greater than the sum of the individual parts. Additionally, the benefits derived from developing the soldier system like other major weapon systems by applying a systems approach will result in accelerated product development cycles, lowered acquisitions costs, and reductions in overall size, weight and power requirements. The bottom line is that the lethality, predictability, flexibility, capability, and "smartness" of a lightweight soldier system is critical to DoD's future warfighting and peacekeeping capabilities. The application of this synergy and integration at the system level are delineated in the demonstrations identified throughout this chapter.

2. Relationship to Operational Capabilities

The five major soldier system operational capabilities are command and control (C^2), lethality, survivability, sustainability, and mobility.

Command and control is the soldier's ability to direct, coordinate, and control personnel, weapons, equipment, information, and procedures necessary to accomplish the mission. Command, control, and communications have combined-arms-compatible systems providing total situational awareness. This is supported by the aggregated capabilities of the soldier's radio and computer (using the Army's emerging architecture), integrated with digital head-mounted displays, combat identification, and navigation aids. Improvements will focus on individual communications, computer control systems, position navigation, information fusing and management, visual and aural enhancement (including image capture and transmission), and situational enhancement.

Lethality is the soldier's ability to detect, recognize, and destroy the enemy targets. Lethality systems will enhance individual, crew, and personal combat weapons with improved effectiveness. The Objective Individual Combat Weapon (OICW) ATD is the lethality component of the soldier system and will provide the capability to attack fortified, non-line-of-sight targets and targets that have gone to ground. The land warrior (LW) capabilities will provide accurate, rapid,

automated target handover to indirect fire support, enhancing the lethality of the total force.

Survivability is the ability to protect oneself against weapon impacts and environmental conditions. The primary requirement for survivability is a "capability to place accurate fire on the enemy without exposing oneself to fire," which will be accomplished through the integration of the OICW fire control and the LW system. Survivability systems will integrate multiple threat protection against ballistic, flame/thermal, chemical/biological, directed energy, surveillance, and environmental hazards. Combat identification capabilities will be integrated into soldier systems to minimize fratricide. Exploitation of the digital net, coupled with inherent enhancements, will significantly improve the survivability of the individual soldier and the entire force through increased controlled dispersion and a common picture of the battlefield.

Sustainability is the ability to maintain the force in a tactical environment. Sustainability systems will be adaptable to all levels of operations on the dynamic battlefield. Features include advanced quality field A-rations, nutritional tailoring to enhance physical and mental performance, a capability to eat on the move, individual purification of all water sources, and improvements in field feeding and field services. Sustainability also includes individual soldier power sources for low-power-draw tactical system components (e.g., computer/radio, helmet system, fire control).

Mobility is the ability to move about the battlefield with accompanying load to execute assigned missions. In the far term, it is envisioned that combat load handling devices will be employed to reduce the combat load of the dismounted soldier. Future mobility systems will allow accurate rapid air insertion for personnel, supplies, and equipment from ultra-high to very low altitudes at maximum airspeeds. Enhancing dismounted operations in snow and ice and at night will also be addressed. Advanced mobility sensors, coupled with the navigational aids (e.g., GPS, digital maps/overlays), greatly enhance the speed and accuracy of night maneuverability of the individual and unit.

The Army's soldier modernization strategy calls for the demonstration, development, and integration of a series of systems and system upgrades. Soldier S/SUs have their greatest impact in the functional areas of dismounted battlespace, battle command, combat service support, and early entry. New operational capabilities that will be afforded in each of these functional areas are listed in Table III–17.

3. Soldier Systems Modernization Strategy

The goal of soldier systems modernization is to develop a fully integrated modular system that will allow the Army to field multiple configurations by tailoring software and hardware for specific unit missions and locations on the battlefield. Modularity will allow commanders and individual soldiers to perform their missions better by carrying only the required components, consistent with mission, enemy, troops, terrain, and time (METT–T).

To support planned materiel development programs for the soldier, the Army's S&T community continues to explore and demonstrate a full range of state-of-the-art technologies. This will maximize the soldier's battlefield capabilities.

The Land Warrior system is operationally focused on the U.S. Army Infantry, the U.S. Marine Corps (infantry), and the U.S. Special Operations Forces. This sytem will be the link into the digitized force of the future using the Army's emerging technical architecture. The result will be enhanced survivability, situational awareness, and lethality at both the individual and the unit level. To ensure that the future dismounted infantry soldier is the best equipped in the world, the Force XXI Land Warrior (FXXI LW) S&T program was established. FXXI LW S&T strategy is responsible for ensuring future battlefield dominance of all dismounted infantry. Advanced technologies in microelectronics, weaponry, and protection will be systematically

Table III–17. Soldier System Capabilities

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
LETHALITY							Laser market, 300-m viewing range	
System							Interface to mini eye-safe laser IR observation set	
Objective Family of Small Arms	○	●		●	○	●	Thermal weapon sight, 550-m range to detect man-sized targets	
Objective Sniper Weapon	○	●		●	○	●	Increased accuracy, P_h, and range	
							Lightweight system	
System Upgrade							Increased P_h and P_i	
Objective Individual Combat Weapon (OICW)	○	●		●	○	●	1000-m viewing range for aim light Increased range and effectiveness of munitions	
Objective Crew Served Weapon (OCSW)	○	●		●	○	●	Decisive violent target effects High P_k Lightweight two-man weapons Immediate incapacitation	
Force XXI Land Warrior	○	●	○	●	○	○	Integrated sight—FLIR integrated with laser rangefinder, compass, aim light, and daylight camera Integrated combat ID—interrogator with laser pointer and training laser Enhanced weapon interface to reduce weight and complexity of LW weapon system	System weight reduction Minimization of system power and energy System life-cycle cost reduction Improved system fightability

Table III–17. Soldier System Capabilities (continued)

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
COMMAND & CONTROL								
System								
Land Warrior	○	●	●	●	○	○	Computer/soldier radio system with GPS (5 lb) Computer/secure squad radio/soldier radio system with handheld flat panel display and GPS (7 lb) Monochrome HMD GPS locator Color overlays and maps on palm-top display Automated reporting software Interactive embedded training Video capture and transfer (single frame) NBC monitoring Integrated high-capacity tactical computer with extended range radio (=23 lbs) High-resolution flat-panel HMD SINCGARS improvement program (SIP) gateway to higher echelons (e.g., CAC^2) at platoon GPS plus self-contained navigation Computer input by voice or "free screen" Color video capture and transfer (single frame plus modem) Automated medical and NBC monitoring Immediate incapacitation	
System Upgrade								
Force XXI Land Warrior	○	●	●	●	○	○	Enhanced soldier radio to increase link margin and range System voice control for voice activation of all LW computer/radio functionality	

Table III–17. Soldier System Capabilities (continued)

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
MOBILITY							Integrated navigation for accurate geolocation when GPS is unavailable	
System Upgrade								
Force XXI Land Warrior		○	●	●	○	○	Voice control for hands-free operation Head orientation sensor	
Advanced Personnel Airdrop Technologies	●	○		●	●	○	Higher altitude personnel parachute opening capabilities Improved glide ratio for personnel parachutes Lower ground impact velocities for airborne soldiers	
SURVIVABILITY							HMD (fix weapon without self-exposing) Body armor	
System								
Land Warrior		●	○		○		Laser detector	
System Upgrade							Combat ID functionality to positively ID friendly forces both LW and non-LW	
Force XXI Land Warrior		●	○		○		SINCGARS SIP+ capability to provide air-to-ground combat ID	
SUSTAINABILITY							Lightweight, low-volume, shelf-stable rations	
System Upgrade							Optimized acceptance/ consumption	
Army Field Feeding Future	○					●	Improved operational flexibility Performance enhances/ around the clock	

● Provides significant capability ○ Provides some capability

applied to the individual soldier, marine, and special operators to augment their operational capabilities to achieve maximum synergy between human and equipment performance.

4. Soldier System Modernization Roadmap

Table III–18 presents the demonstrations and systems that are part of the soldier systems modernization roadmap (see Figure III–11).

a. Command and Control Demonstrations

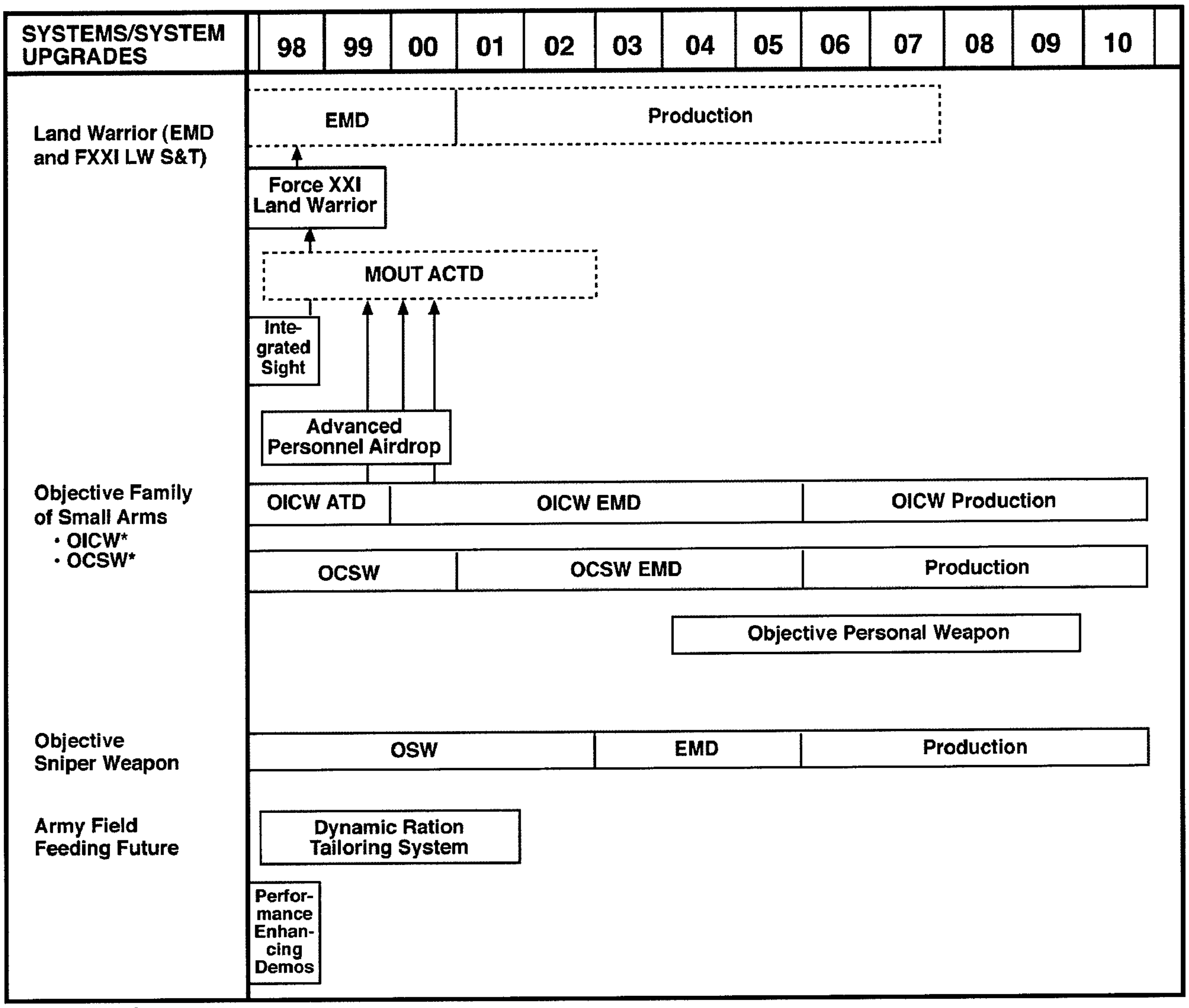
Force XXI Land Warrior (FXXI LW) TD (1996–99). The primary objectives of FXXI LW are to:

- Demonstrate candidate advanced technology upgrades to the LW system.
- Develop a revolutionary technology path to support future development of an ultra-lightweight, low-power, dismounted warfighter system resulting from scientifically based operational analyses.
- Provide linkage with MOUT ACTD, small unit operations (SUO), and other warfighter technology programs.

This project addresses the critical Army need to enhance the performance, lethality, survivability, and sustainment of the individual soldier. This project is the Land Warrior S&T program. In the near term, the FXXI LW efforts will focus on the evolutionary technology insertions to the LW system. These technologies include an enhanced weapon and sensor interface to increase reliability, reduce weapon weight, and increase usability; an integrated navigation component that will provide soldiers with accurate geolocation information when GPS is not available; an enhanced soldier radio that will provide a better link margin for the soldier radio and increased radio range; system voice control that will provide voice control of essential LW functions without the use of a hand-controlled device; combat identification functionality that will provide positive identification of friendly LW and non-LW combatants; low power helmet electronics that will reduce the overall power requirements of the LW helmet system; and a head orientation sensor, which, in combination with weapon-mounted sensors, will provide a rapid target acquisition capability when switching between the image intensifier and the weapon sight. Another FXXI LW component is the Integrated Sight TD that will demonstrate a lighter, fully integrated

Table III–18. Soldier Demonstration and System Summary

Advanced Technology Demonstration	Technology Demonstration
Objective Individual Combat Weapon	Force XXI Land Warrior
	Integrated Sight
	Advanced Personnel Airdrop
Advanced Concept Technology Demonstration	Dynamic Ration Tailoring System
	Performance Enhancing Demonstrations
Military Operations in Urban Terrain	Objective Personal Weapon
	Objective Sniper Weapon
	Objective Crew-Served Weapon
System/System Upgrade/Advanced Concept	
System	**System Upgrade**
Land Warrior (EMD)	Force XXI Land Warrior
Objective Family of Small Arms	Army Field Feeding Future
Objective Sniper Weapon	Objective Individual Combat Weapon
	Objective Crew-Served Weapon
	Advanced Personnel Airdrop Technology



*System upgrade.

Figure III–11. Roadmap—Soldier System Modernization

weapon sensor (thermal, laser pointer, laser rangefinder, digital compass, daylight camera), with integrated target handover functions.

In FY99, the FXXI LW program will perform an early user test (EUT) to validate the improvement of advanced technologies for the Land Warrior system. This EUT will demonstrate the improved individual and small-unit operational effectiveness afforded by the modular integration of advanced components onto the LW platform. These results will be utilized to ensure that future LW procurements are upgraded with current technology advancements. Other emerging technology base components from ongoing (DTO, ATD, STO, and DARPA) efforts will also be considered as candidates for technology insertion onto the LW platform. FXXI LW will also pursue a variety of future technology developments for upgrading the LW platform. This effort will chart a course for future LW modernization with a focus on technologies available for fielding in the FY05–08 timeframe. The focus of these improvements will be system weight reduction, minimization of system power and energy requirements, system life-cycle cost reduction, and improved system fightability. This program will leverage the commercial microelectronics and telecommunications industries as well as

other ongoing DoD programs, such as DARPA's SUO program, to achieve lightweight, miniaturized components.

This program will make extensive use of IPPD to ensure that all critical manufacturing processes are developed in parallel to the design of the technical components. As such, each product will be developed in an integrated product team environment. This approach will ensure a viable, affordable, and producible product that will perform as expected in the field.

This strategy will accelerate the fielding of technology upgrades and ensure that the United States maintains a global technology overmatch for dismounted warrior combat systems. *Supports:* MOUT ACTD and SUO.

b. Lethality Demonstrations

The lethality demonstrations will focus on weapons, munitions, and target detection and acquisition.

Objective Individual Combat Weapon (OICW) ATD (1994–99). The OICW, as defined in the *Joint Service Small Arms Master Plan* (JSSAMP) and the approved mission need statement (MNS), is the next-generation individual weapon envisioned to replace some of the current inventory of small arms weapon systems. Two OICW concepts are being developed by competing contractor teams. Both concepts include kinetic energy (5.56 mm) and airburst (20 mm) munitions. A significant new capability afforded by OICW will be the ability to defeat targets that are in defilade, using bursting munitions. This ATD will demonstrate the potential of the OICW to provide an overmatch against threat infantry soldiers, as required in the JSSAMP. It will involve realistic operational assessments with troops and key on the soldier's ability to acquire and defeat targets. The performance potential of the OICW will be assessed against the baseline M16A2/M203 and the modular weapon. Measures of effectiveness include probability of hit, probability of incapacitation, kills per combat load, and cost per kill. The significant potential of the OICW in an urban environment will be demonstrated in the MOUT ACTD. The technologies exploited to achieve the overmatch capability include high-strength, ultra lightweight materials, high-technology miniaturized fuzes, high-explosive-air-bursting projectiles, electronic ranging, ballistic computation, reticle displacement, video sighting, and sophisticated fire control devices. *Supports:* OICW and MOUT ACTD.

The Objective Crew-Served Weapon (OCSW) TD (1996–01). Part of the objective family of small arms, the OCSW demonstration will support the two-man, crew-served weapon outlined in the JSSAMP. This demonstration will establish the feasibility of a lightweight, two-man-portable crew-served weapon system capable of defeating personnel and light vehicle targets to 2,000 meters. This TD is discussed in further detail in the section on Close Combat Light (above). *Supports:* MOUT ACTD.

Objective Sniper Weapon (OSW) TD (1997–02). The OSW is the single-sniper weapon that will achieve the required future capabilities of the joint sniper communities, to include conventional military, special operations forces, and law enforcement. Its increased precision and range will enable the sniper to engage targets, humans (protected or unprotected), and light materiel more effectively out to 2,000 meters. Additionally, it will have increased accuracy and hit probability. This lightweight system will be operational day or night, in all weather conditions, and on land, sea, or air and will weigh 10 to 15 pounds. *Supports:* OSW.

Integrated Sight (IS) TD (1994–98). The IS TD will develop and demonstrate optimum components and integration of a thermal imager, laser rangefinder, electronic compass, and near IR pointer into a compact sighting system. Imagery and data will be output to the LW HMD and soldier's computer. These technologies will provide the soldier with extended range and automated targeting capabilities. IS also supports advanced weapons, including the OICW and OCSW. *Supports:* Lightweight Laser Designator/

Rangefinder (which incorporates IS technologies or components in their fire control).

Objective Personal Weapon (OPW) TD (2004–09). The OPW is the sidearm of the future. It will provide increased accuracy and incapacitation for close-in self-defense in last-ditch combat situations, as well as some extended offensive capability in special operations, military police operations, and dignitary protection. The envisioned OPW will employ technically advanced, leap-ahead concepts and technologies that span the entire electromagnetic spectrum, yielding incapacitating mechanisms of a nonconventional nature. It will be capable of immediate incapacitation (target ceases to remain a threat) out to 50 meters against personnel with body armor. It will have substantially increased accuracy, hit probability, and target effects. This lightweight system will not exceed 3 pounds and will be user friendly with hands-free carry. It will provide multiple engagement capability and be operational day or night, in all weather conditions, on land/sea/surf/air. *Supports:* Objective Family of Small Arms.

c. Mobility Demonstrations

Advanced Personnel Airdrop TD (1998–00). This TD will demonstrate technologies to provide improved performance characteristics and enhanced safety of existing personnel parachute capabilities. Utilizing advanced airfoil and parachute designs, the TD will demonstrate, by the end of FY98, a gliding personnel parachute with a 20 percent increase in maximum jump altitude and a 25 percent increase in glide ratio, when compared to the current Army state-of-the-art MC–4 parachute. By the end of FY99, the TD will demonstrate a nonparachute, soft-landing capability that will reduce descent rates to values below 16 feet/second, utilizing "pneumatic muscle" technologies.

The planned gliding personnel parachute would allow for jump altitudes up to 30,000 feet, with reduced opening shock and a glide ratio of 2.5 to 1. The current MC–4 has a maximum jump altitude of 25,000 feet and roughly a 2 to 1 glide ratio. The planned soft-landing capability will be a nonparachute decelerator that will slow the jumper to a descent rate below 16 feet/second, moments before landing on the drop zone. *Supports:* STOp–H16 (Airborne Insertion for Operations in Urban Terrain), the Advanced Tactical Parachute System development effort, and Battle Laboratory Future Operational Capabilities (FOCs) (EELS 97–016 and IN 97–301).

d. Other Soldier Systems Demonstrations

Military Operations in Urban Terrain (MOUT) ACTD (1998–02). The MOUT ACTD is a joint (Army/Marine Corps) program that encompasses a breadth of technologies ranging from an advanced soldier system, advanced individual precision weapons, combat identification, counter-sniper nonlethal weapons, advanced sensors, situational awareness, and personal protection. The core capability that will be generated via the ACTD is a linkage of a series of advanced systems/components into a MOUT system-of-systems whereby the components are interfaced, integrated, or linked in an architecture to ensure their effective interoperability and functionality in the challenging MOUT environment. The integrated MOUT system-of-systems will provide a robust and enhanced joint operational capability encompassing the areas of urban C^4I, engagement, and force projection. *Supports:* Upgrades to FXXI LW.

Dynamic Ration Tailoring System TD (1998–01). A dynamic ration module selector system will be developed and demonstrated that tailors the calorie-providing and performance-enhancing components to the combat situation and time of the day to ensure a dominant and lethal warfighter in any environment and for any mission. The eat-on-the-move, round-the-clock, ration selection system continually considers the nutritional and energy requirements and specifics, as well as what and when rations are to be consumed for optimal combat performance. *Supports:* Army Field Feeding Future.

Performance Enhancing Demonstrations TD (1995–98). Special supplemental components containing ingredients to enhance performance under stressful conditions during sustained operations will be developed and demonstrated. These components will supplement the individual combat ration to increase mental acuity and situational awareness, extend endurance, and reduce the effects of high–altitude sickness. *Supports:* Army Field Feeding Future.

5. Relationship to Modernization Plan Annexes

The Soldier systems S/SU linkages with other AMP annexes are shown in Table III–19.

Table III–19. Correlation Between Soldier Systems S/SU/ACs and Other AMP Annexes

System/System Upgrade/Advanced Concept		Modernization Plan Annexes									
		Mounted Forces*	Close Combat Light*	Aviation	C^4	Fire Support	Engineer & Mine Warfare*	IEW	NBC	Combat Health Support	Training
System	Objective Family of Small Arms		●	○		○					
	Land Warrior (EMD)	○	●	○	●	●	○	●	●	○	●
	Objective Sniper Weapon	○	●			●					
System Upgrade	Army Field Feeding Future	○	○							○	
	Objective Individual Combat Weapon		●								
	Objective Crew-Served Weapon	○	●								
	Advanced Personnel Airdrop Technologies		●								
	Force XXI Land Warrior	○	●	○	●	●	○	○	○	○	●

* See Combat Maneuver Annex.
● System plays a significant role in the modernization strategy
○ System makes a contribution to the modernization strategy

J. COMBAT HEALTH SUPPORT

The mission of the Army Medical Department is to provide world class combat casualty care to America's most precious resource, its sons and daughters, in peace and war.

General Maxwell R. Thurman

1. Introduction

The major goals of the Army combat health support (CHS) S&T program are three: first, to prevent illness and injury; second, to sustain optimum military effectiveness; and third, to treat casualties. The greatest payoff from the investment in CHS S&T comes from the identification of medical countermeasures that eliminate health hazards. Preventive measures include biomedical technologies, information and materiel to protect the force from infectious disease, environmental injury, health hazards of combat systems, operational stress, and aggressor weapons (i.e., conventional, chemical, biological, and directed-energy systems).

Biomedical research provides vaccines, pretreatment drugs, and training strategies that maximize the readiness of soldiers to deploy and fight. Biomedical research assists leaders in optimizing warfighting capabilities across the full continuum of conflict, from peacekeeping to high-intensity combat. Biomedical research also provides the means to maximize far-forward diagnosis, treatment, and return-to-duty of combat casualties. Medical contributions unique to the military include such items as field-deployable diagnostic kits, vaccines and antidotes for chemical and biological warfare threat agents, resuscitative devices for field use, and enhanced medical evacuation platforms.

2. Relationship to Operational Capabilities

Key points in developing CHS are the scenario and METT–T, as well as the medical intelligence assessment of the battlefield, which includes threats to the health of the soldier. The probability for success of the force during operations will be greater if the force is psychologically, physically, and nutritionally fit; protected from illness through a vigorous vaccination program; and sustained through state-of-the-art medical care as limited by the battlefield environment. As battle and nonbattle health threats are reduced, casualties and force requirements will be reduced correspondingly. Fulfilling the vision of the Army modernization objectives will require significant input from the military CHS S&T community. Examples of biomedical technologies impacting Army operations are: vaccines, pretreatments, and treatments against endemic infectious diseases and CB threat agents; nutritional strategies; medical information products; environmental and behavioral performance models; improved capability for far-forward surgical stabilization of combat casualties; enhanced ground and aeromedical evacuation; and medical telepresence technologies.

The capabilities of CHS S/SU/ACs supporting Army modernization objectives appear in Table III–20.

3. Combat Health Support Modernization Strategy

Modernization efforts are organized into four functional areas: infectious diseases of military importance, medical chemical and biological defense, combat casualty care, and Army operational medicine. Efforts focus on the development of medical materiel, through a DoD drug and vaccine program, for countering potential mission-aborting infectious diseases as well as chemical and biological warfare agents. Such drugs and vaccines are not normally developed by the U.S. pharmaceutical industry, because there is little or no civilian market for them within the industrialized nations and they are typically unprofitable. Additional emphases of the biomedical program include technologies supporting far-forward casualty treatment; individual sustainment (self-aid devices and techniques) to reduce the severity of ballistic injuries; topical

Table III–20. Combat Health Support System Capabilities

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
INFECTIOUS DISEASES OF MILITARY IMPORTANCE							Protection against blood and tissue stages of malaria	Protection against malaria using a combined vaccine
System/System Upgrade							Treatments for drug-resistance malaria	Combined oral vaccine for protection against diarrheal disease
Infectious Disease Pharmaceuticals	●	●			○	○	Protection against *Shigella*	CAD-, molecular fingerprinting-, and molecular biology-based drug discovery
Infectious Disease Vaccines	●	●			○	○	Protection against Campylobacter	Forward deployed, handheld, multiagent nucleic-acid-based diagnostic device
Infectious Disease Applied Medical System	○	●	○		○	○	Protection against enterotoxigenic *E. coli*	
Advanced Concept							Protection from Dengue fever	
Medical Prevention and Treatment of Malaria	●	●			○	○	Forward diagnostic test kits for rapid detection of infectious disease agents	
Medical Prevention of Diarrheal Diseases	●	●			○	○		
Medical Prevention of Dengue Fever	●	●			○	○		
Early and Rapid Disease Threat Assessment	○	●	○		○	○		
MEDICAL CHEMICAL AND BIOLOGICAL DEFENSE							Protective vaccines against encephalomyelitis, botulinum toxin, staphylococcal enterotoxin, anthrax, plague, Brucella, and ricin	Multiagent protection with single vaccination
System/System Upgrade							Rapid identification and diagnosis	Definitive, handheld, far-forward diagnostic capabilities
CW/BW Casualty Management	○	●				○	Improved chemical casualty management	Advanced skin/wound decontamination
CW Prophylaxes and Treatments	○	●				○	Prevention of cyanide toxicity	Reduced vesicant injury
BW Countermeasures	○	●				○		Advanced anticonvulsant
Advanced Concept								Advanced topical ointment protection against multiple chemical agents
CW/BW Casualty Management System	○	●				○		Advanced BW treatments
Full-Spectrum Chemical Protection	○	●				○		
Multiagent Protective System	○	●				○		

Table III–20. Combat Health Support System Capabilities (continued)

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
COMBAT CASUALTY CARE							Improve blood storage duration Localize antibiotic administration Enhance monitoring and diagnosis far-forward Enhance control of hemorrhage Infuse blood far-forward Provide enhanced en-route care and far-forward anesthesia Provide a medical assist algorithm for treatment/ triage	Modulate immunosuppression and prevent sepsis Enhance medical diagnostics and communications for casualty care Induce reduction in metabolic requirements Preserve cell/organ function by drug administration Provide lightweight energy generators Use nanomaterials for non-invasive sensors, smart systems, and treatment modalities
System/System Upgrade								
Hemorrhage/Trauma Intervention	○	●				○		
Life Support/Surgical Systems	●	●	○		○	○		
Advanced Concept								
Advanced Resuscitation	○	●				○		
Immediate Intervention and Continuum of Care	●	●	○		○	○		
ARMY OPERATIONAL MEDICINE							Performance—enhancing nutritional supplements Reduction and prevention of deployment stress Protection criteria for military systems Performance limits model	Performance optimization Sleep and alertness enhancement Physiological models
System/System Upgrade								
Performance Sustainability	●	●		○	○	●		
Protection Criteria	○	●				○		
Physiological Status Modeling	○	●	○			○		
Advanced Concept								
Soldier Survival in Continuous Operations Without Performance Decrements	●	●			○	●		
Biomedical and Performance and Damage Criteria	○	●				○		
Real-Time Soldier Effectiveness Models	●	●	○			●		

● Provides significant capability ○ Provides some capability

skin protectants; and forward-deployable, transportable medical devices, and multipurpose systems for advanced resuscitation, life support, and resuscitative surgery. The modernization strategy also addresses nutritional, biomechanical, and physiological approaches to minimize the impact of military operational stresses that degrade the capabilities of, or render inoperable, the human component of combat systems.

The development of enabling technologies to maximize the benefits of telemedicine is a further objective of the CHS modernization strategy. In essence, telemedicine represents a horizontal integration of advanced medical technologies, inasmuch as efforts within each of the four functional areas identified above have the potential to contribute to expanded telemedicine capabilities. Present CHS S&T efforts relevant to telemedicine are concentrated in the combat casualty care and Army operational medicine functional areas.

4. Combat Health Support Modernization Roadmaps

Table III–21 presents a summary of demonstrations and S/SU/ACs listed in the combat health support modernization roadmaps (Figures III–12 through III–15). Army CHS S&T programs support a diversity of nonmateriel advanced development TDs. Unlike most nonmedical TDs, medical TDs must be conducted in a laboratory, rather than in the field, because of the regulatory requirements placed on medical materiel by the Department of Health and Human Services, through the U.S. Food and Drug Administration (FDA).

The FDA requires that medical products (e.g., vaccines, medical devices, drugs) demonstrate preclinical safety and efficacy prior to product evaluation in man. Thus, the medical system acquisition process has led to a tailored life-cycle system management model for medical materiel. It is in the TD phase of the medical materiel life cycle that technology candidates are fully evaluated for preclinical (prior to human use) safety and efficacy. The best candidates are then selected for transition. Descriptions of major TDs are provided on the following pages. Dates provided in the text reflect the timeline of the product from technology base research to development (milestone I), or, in the case of information products, to direct fielding to the user community.

a. Infectious Diseases of Military Importance Demonstrations

Systems supported within this functional area are infectious disease vaccines, infectious disease pharmaceuticals, and infectious disease-applied medical systems. Vaccines provide a relatively inexpensive, extended protection against infectious disease threats. While they are the preferred mechanism of protection in most cases, and are an ultimate goal, they do not currently provide complete protection against all infectious diseases. Until such vaccines are available, the continual emergence of new resistant strains of infectious diseases necessitates the ongoing development of new antiparasitic drugs to replace existing products. Moreover, improved diagnostic capabilities are needed to enable early far-forward identification and appropriate management of diseases for which there is no current protection, and to facilitate global surveillance of emerging infectious diseases. The modernization roadmap for infectious diseases of military importance is shown in Figure III–12. Future demonstrations, which are shown in the roadmap, are funded, follow-on efforts to current technology demonstrations. Since the technology and direction of the future demonstrations will not be identified until closer to the start date, they are not explained in the following narratives. Innovative diagnostic and vaccine technology development in the infectious diseases functional area also supports and is supported by efforts in the medical, chemical, and biological defense area.

Antiparasitic Drug Program TD (1985–03). The effectiveness and safety of a variety of drugs from differing pharmacological classes will be demonstrated to provide prophylaxis and treatment against established and emerging forms of drug-resistant falciparum and vivax malarias and leishmaniasis. Several classes of drugs are being assessed for treatment and prophylaxis. *Supports:* Medical Prevention and Treatment of Malaria.

Table III–21. Combat Health Support Demonstration and System Summary

Advanced Technology Demonstration	Technology Demonstration
There are currently no Army CHS ATDs.	**Infectious Diseases of Military Importance**
	Antiparasitic Drug Program
	Malaria Vaccines
	Combined Malaria Vaccine
	Shigella Vaccines
	Campylobacter Vaccine
	Entertoxigenic *Escherichia coli* Vaccine
	Oral Multidisease Antidiarrheal Vaccine
	Dengue Virus Vaccine
	Common Diagnostic Systems for Biological Threats and Endemic Infectious Diseases (shared demonstration)
	Medical Chemical and Biological Defense
	BW Agent Confirmation Diagnostic Kit
	Common Diagnostic Systems for Biological Threats and Endemic Infectious Diseases (shared demonstration)
	Advanced Anticonvulsant
	Reactive Topical Skin Protectant/Decontaminant
	Cyanide Pretreatment
	Chemical Agent Prophylaxes
	Medical Countermeasures Against Vesicant Agents
	Medical Countermeasures for *Yersinia pestis*
	Medical Countermeasures for Brucellosis
	Medical Countermeasures for Encephalomyelitis Viruses
	Medical Countermeasures for Filoviridae
	Medical Countermeasures for Variola
	Medical Countermeasures for Botulinum Toxin
	Medical Countermeasures for Ricin
	Recombinant Staphylococcal Enterotoxin B Vaccine
	Multiagent Vaccines for Biological Threat Agents
	Combat Casualty Care
	Blood/Loss Resuscitation
	Secondary Damage After Hemorrhage
	Forward, Mobile, Digitally Instrumented Surgical Hospital
	Warrior Medic
	Far-Forward Medical/Surgical Devices
	Army Operational Medicine
	Continuous Operations Nutrition and Metabolic Requirements
	Biomechanical Performance Optimization
	Wake/Rest Enhancement Strategies
	Deployment Stress Countermeasures
	Performance Limits in Extreme Environments
	Warfighter Readiness and Sustainability
	Deployment Toxicology Assessment Methods
	Laser Bioeffects and Treatment
	Whole Body Blast Bioeffects/Blunt Trauma Models
	Mechanical Stress and Helicopter Crew Protection

Table III–21. Combat Health Support Demonstration and System Summary (continued)

System/System Upgrade/Advanced Concept	
System/System Upgrade	**Advanced Concept**
Infectious Disease Pharmaceuticals	Medical Prevention and Treatment of Malaria
Infectious Disease Vaccines	Medical Prevention of Diarrheal Diseases
Infectious Disease Applied Medical Systems	Medical Prevention of Dengue Fever
	Early and Rapid Disease Threat Assessment
CW/BW Casualty Management	CW/BW Casualty Management System
CW Prophylaxes and Treatments	Full-Spectrum Chemical Protection
BW Countermeasures	Multiagent Protective System
Hemorrhage/Trauma Intervention	Advanced Resuscitation
Life Support/Surgical Systems	Immediate Intervention and Continuum of Care
Performance Sustainability	Soldier Survival in Continuous Operations Without Performance Decrements
Protection Criteria	Biomedical and Performance Damage Risk Criteria
Physiological Status Modeling	Real-Time Soldier Effectiveness Models

Malaria Vaccines TD (1985–02). Candidate vaccines against falciparum and vivax malarias will be demonstrated. Innovative vaccine technologies are being used to construct protective vaccines, including recombinant vaccines, naked DNA vaccines, and peptide vaccines. *Supports:* Medical Prevention and Treatment of Malaria.

Combined Malaria Vaccine TD (2003–08). The feasibility of a combined falciparum/vivax malaria vaccine that incorporates advanced vaccine technology, such as DNA vaccines, will be assessed. This vaccine will reduce logistical burden and simplify medical delivery. *Supports:* Medical Prevention and Treatment of Malaria.

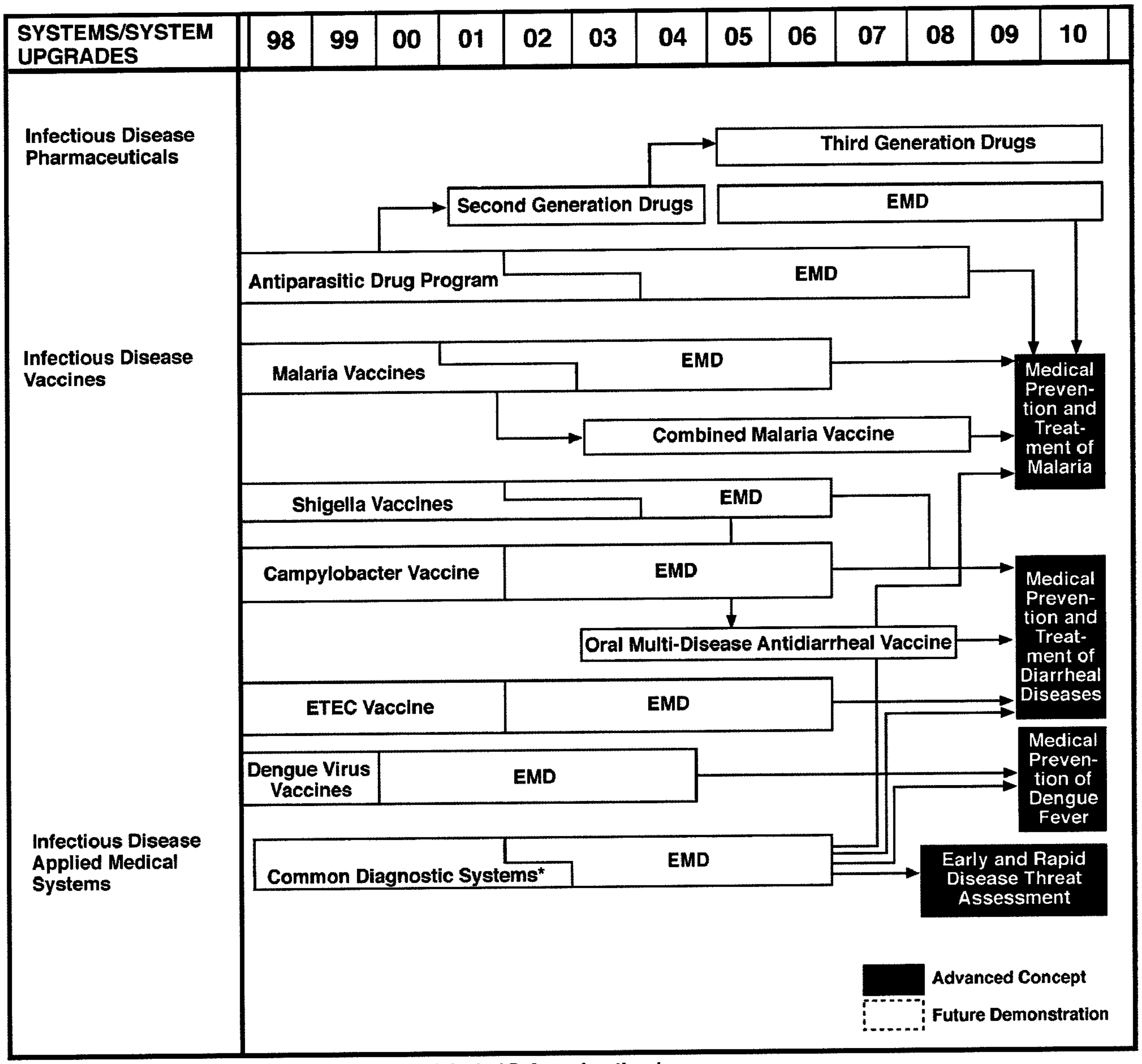
***Shigella* Vaccines TD (1985–03).** Candidate vaccines against each of the three principal causal *Shigella* species of dysentery will be demonstrated. Traditional vaccine technology using live attenuated (weakened) forms of the pathogen and a new vaccine technology, the proteosome/lipopolysaccharide vaccine system, will be demonstrated. *Supports:* Medical Prevention of Diarrheal Diseases.

Campylobacter Vaccine TD (1985–01). A vaccine to protect against Campylobacter will be demonstrated, using novel immune adjuvants. Two candidate vaccine strategies are being assessed: a killed, bacterial preparation and a live, attenuated organism. *Supports:* Medical Prevention of Diarrheal Diseases.

Enterotoxigenic *Escherichia coli* (ETEC) Vaccine TD (1985–01). Major protective antigens have been identified and recombinant DNA technology is being used to produce these components and combine them with a new form of adjuvant incorporated into biodegradable microspheres. *Supports:* Medical Prevention of Diarrheal Diseases.

Oral Multidisease Antidiarrheal Vaccine TD (2003–08). The feasibility of producing a more effective, combined oral vaccine to protect against *Shigella,* Campylobacter, and ETEC will be assessed. Advanced vaccine technology, such as recombinant or naked DNA technology, and advanced mucosal adjuvants will be demonstrated. This vaccine will be easily administered, thereby reducing medical and logistical support requirements. *Supports:* Medical Prevention of Diarrheal Diseases.

Dengue Virus Vaccines TD (1985–99). Component vaccines against the four antigenically different forms of the virus will be combined into one vaccine. Selection of appropriate vaccine component parts and their integration will be demonstrated. *Supports:* Medical Prevention of Dengue Fever.



*Shared demonstration with Medical Chemical and Biological Defense functional area.

Figure III–12. Roadmap—Combat Health Support: Infectious Diseases of Military Importance

Common Diagnostic Systems for Biological Threats and Endemic Infectious Diseases TD (1998–02). This demonstration is shared with the medical, chemical, and biological defense functional area. An immunologically based membrane platform will be demonstrated that requires no special instrumentation and is capable of rapidly detecting specific host immune responses to a broad range of etiologic agents, or detecting the antigens or products of these agents in clinical specimens. A polymerase chain reaction (PCR)-microchip system will also be demonstrated. The latter consists of coupling methodology to detect pathogen-unique DNA with microchip technology to produce an electronic readout. These technologies offer the potential to reduce development time and expense associated with individual assays, decrease logistical and training burdens, and improve medical care delivery forward. *Supports:* Medical Prevention and Treatment of Malaria, Medical Prevention of Diarrheal Diseases, Medical Prevention of Den-

gue Fever, and Early and Rapid Disease Threat Assessment.

b. Medical Chemical and Biological Defense Demonstrations (DoD Funded)

Systems supported within this functional area are CW/BW casualty management, CW prophylaxes and treatments, and BW countermeasures. Efforts focus on the demonstration of medical products for prevention, treatment, diagnosis, and generation of medical knowledge for battlefield management of chemical and biological casualties. Vaccines are generally the products of choice for countering BW agents, owing to their relative simplicity of use and the maximum protection that they provide. In contrast, pharmaceuticals are better suited to counter CW agent threats because, as compared to BW agents, CW agents are much smaller in molecular size. Because of their smaller size, CW agents do not bind tightly to antibodies nor do they induce a protective antibody response.

The modernization roadmap for medical, chemical, and biological defense is shown in Figure III–13. Future demonstrations, which are shown in the roadmap, are funded, follow-on efforts to current technology demonstrations. Since the technology and direction of the future demonstrations will not be identified until closer to the start date, they are not explained in the following narratives. All medical-biological defense products are transitioned to the Joint Vaccine Acquisition Program Project Management Office (JVAP–PMO) for advanced development. Diagnostic and vaccine technology development in this area also supports and is supported by efforts in the Infectious Diseases of Military Importance area.

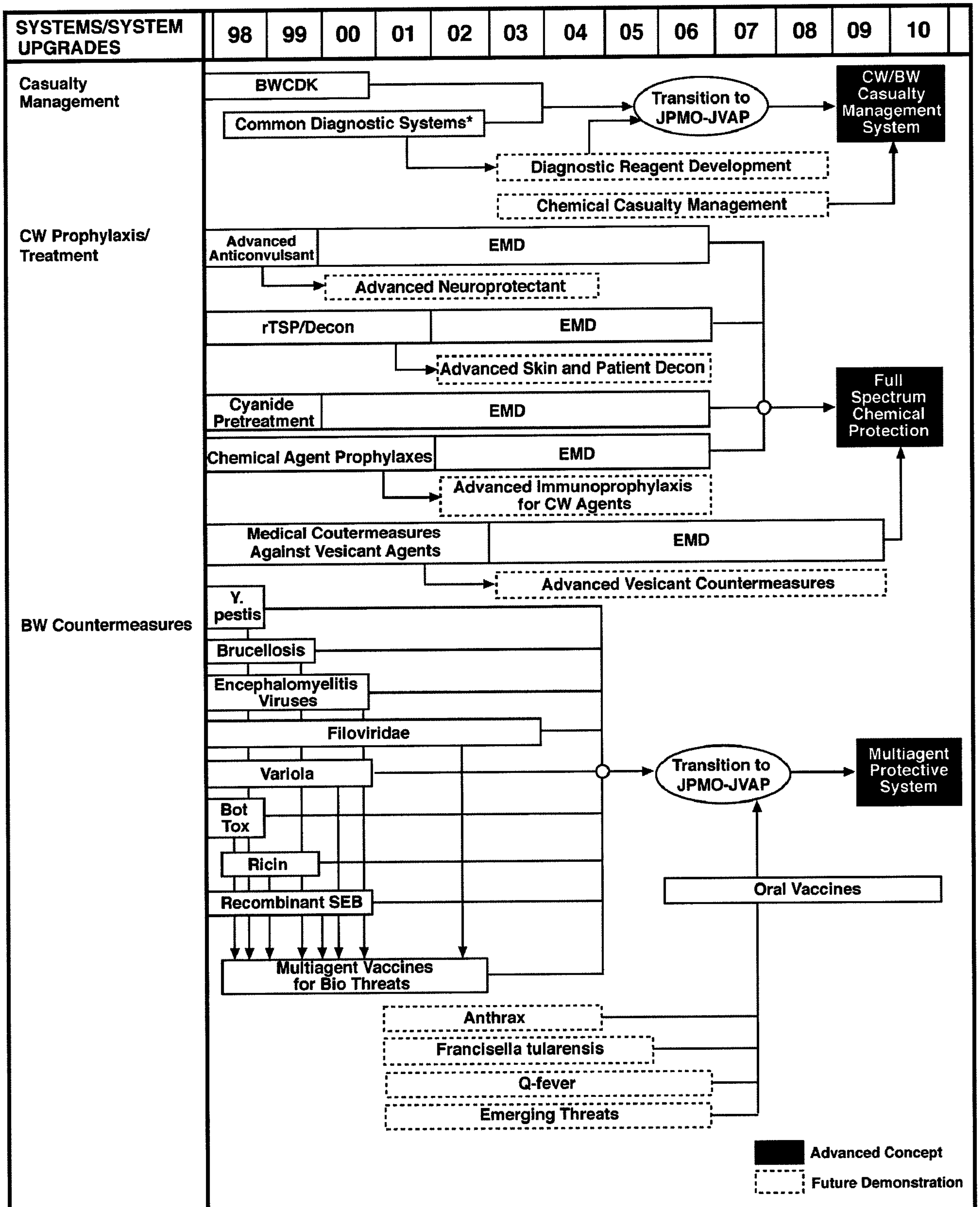
Biological Warfare Agent Confirmation Diagnostic Kit (BWCDK) TD (1996–00). Capability to confirm the initial field diagnosis obtained with the forward-deployable diagnostic kit will be demonstrated. This kit will employ immunodiagnostic reagents directed against independent biological markers, and will provide greater specificity and sensitivity. *Supports:* CW/BW Casualty Management System.

Common Diagnostic Systems for Biological Threats and Endemic Infectious Diseases TD (1998–02). This demonstration is shared with the Infectious Diseases of Military Importance functional area (see description under this functional area). *Supports:* CW/BW Casualty Management System.

Advanced Anticonvulsant TD (1995–99). Safety and efficacy of an anticonvulsant component for the soldier/buddy nerve agent antidote will be demonstrated. This advanced anticonvulsant will overcome deficiencies in the current anticonvulsant, enhance nonrecurrence of seizures, and protect against nerve agent-induced, seizure-related brain damage. Compounds from a variety of pharmacological classes with known anticonvulsant or other relevant neuroactive properties will be screened to identify a drug with relatively pure anticonvulsant actions for inclusion in the existing treatment regime. *Supports:* Full-Spectrum Chemical Protection.

Reactive Topical Skin Protectant/Decontamination (rtsp/Decon) TD (1995–01). A reactive component for a topical skin protectant that will provide protection against penetration of agent and will detoxify both vesicant and nerve chemical warfare agents will be demonstrated. Efforts will explore the use of enzymes and other catalytic molecules and resorptive resins. The rtsp/Decon will enable the soldier to fight in a chemical warfare battlefield with more complete protection and to effect decontamination procedures in a CW-contaminated environment. *Supports:* Full-Spectrum Chemical Protection.

Cyanide Pretreatment TD (1994–99). A methemoglobin formula will be demonstrated as an oral pretreatment to protect soldiers against battlefield levels of cyanide. Methemoglobin preferentially binds cyanide, removing it from the toxic active site, thereby restoring normal cellular respiration. The lead candidate is an



*Shared demonstration with Medical, Chemical and Biological Defense functional area.

Figure III–13. Roadmap—Combat Health Support: Medical Chemical and Biological Defense

8-aminoquinoline that is undergoing safety tests. *Supports:* Full-Spectrum Chemical Protection.

Chemical Agent Prophylaxes TD (1995–01). A reactive/catalytic scavenger pretreatment will be demonstrated that reduces chemical agent toxicity without significant physiological or psychological side effects. Although treatment for nerve agent intoxication exists, the soldier is incapacitated following exposure and treatment. Development of an effective catalytic scavenger would relieve the commander and soldier of having to rely on a multidrug approach to treatment of nerve agent exposure, thereby significantly enhancing recovery. Current efforts focus on the use of a molecularly engineered form of butyrylcholinesterase, an enzyme found in blood, which normally binds to nerve agents. *Supports:* Full-Spectrum Chemical Protection.

Medical Countermeasures Against Vesicant Agents TD (1996–02). New technologies for prophylaxis, pretreatment, and treatment will be demonstrated that will provide significant protection against vesicant injury. This effort will yield a vesicant agent countermeasure that will prevent or decrease the severity of injuries, and substantially reduce casualties and the subsequent medical burden. Protease inhibitors and novel antiinflammatory drugs have shown promising results in early studies and are among the leading candidates for transition. *Supports:* Full-Spectrum Chemical Protection.

Medical Countermeasures for *Yersinia pestis* TD (1994–98). Efficacy and safety will be demonstrated for a novel vaccine based on a fusion protein, produced through molecular recombination and expression of the genes for two different proteins of the pathogen. This vaccine will protect 80 percent of immunized personnel against an aerosol challenge of *Yersinia pestis*. *Supports:* Multiagent Protective System.

Medical Countermeasures for Brucellosis TD (1994–99). This demonstration will compare two candidate vaccine technologies: a mutant live-cell vaccine, and an acellular vaccine based on surface glycoproteins of the pathogen. Safety and efficacy sufficient to protect 80 percent of immunized personnel against an aerosol challenge of *Brucella* will be shown. *Supports:* Multiagent Protective System.

Medical Countermeasures for Encephalomyelitis Viruses TD (1996–00). Efficacy and safety will be demonstrated for a set of vaccines directed against various members of the encephalomyelitis viruses, a group of viruses that cause disorientation, convulsions, paralysis, and death. Site-directed mutagenesis—a molecular biological technique that induces specifically designed mutations in essential genes of the pathogen—will be used to produce organisms that will elicit a protective immune response without causing disease. *Supports:* Multiagent Protective System.

Medical Countermeasures for Filoviridae TD (1998–03). Safe and effective countermeasures against filoviruses, including Marburg and Ebola viruses, will be demonstrated. Naked DNA vaccine technology is currently one of several technologies offering promise for protection against these and other BW threat agents. This technology uses DNA fragments from pathogens of interest, which are then injected into the cells of the outer layer of skin using gene gun technology. In the skin cells, the cell's protein production machinery produces proteins from the pathogen DNA, which then elicits an immune response that can later protect against the live pathogen. Because only portions of the pathogen DNA are used in the vaccine, no live organism is produced during the vaccination process, and the injected DNA is later eliminated as skin cells normally slough off. *Supports:* Multiagent Protective System.

Medical Countermeasures for Variola TD (1997–00). This demonstration will assess the use of human monoclonal antibodies to replace vaccinia immune globulin in providing passive (short-term) immunity. Antiviral drugs for post-exposure treatment will also be screened to identify effective countermeasures. These studies will not use variola itself, but will instead employ an

appropriate orthopox virus substitute. *Supports:* Multi–Agent Protective System.

Medical Countermeasures for Botulinum Toxin TD (1994–98). A vaccine will be demonstrated that will protect 80 percent of immunized personnel against an aerosol challenge of the toxin, provide protection against all significant serotypes, and induce a minimum reactogenicity in immunized soldiers. The vaccine to be demonstrated has been developed using recombinant DNA technology to produce a bioengineered product that has lost its toxic properties, yet still elicits a protective immune response. This bioengineered product is expected to be safer to produce, less reactogenic in man, and more affordable than vaccines produced with other technologies. *Supports:* Multiagent Protective System.

Medical Countermeasures for Ricin TD (1998–99). This effort will demonstrate efficacy and safety of a second-generation vaccine against ricin. The vaccine candidate is based on a modified portion of the ricin molecule. *Supports:* Multiagent Protective System.

Recombinant Staphylococcal Enterotoxin B (SEB) Vaccine TD (1994–00). A bioengineered vaccine will be demonstrated that will protect 90 percent of immunized animals against a lethal and incapacitating aerosol challenge of SEB. This second-generation recombinant product will offer potential safety and affordability advantages over the first-generation product. *Supports:* Multiagent Protective System.

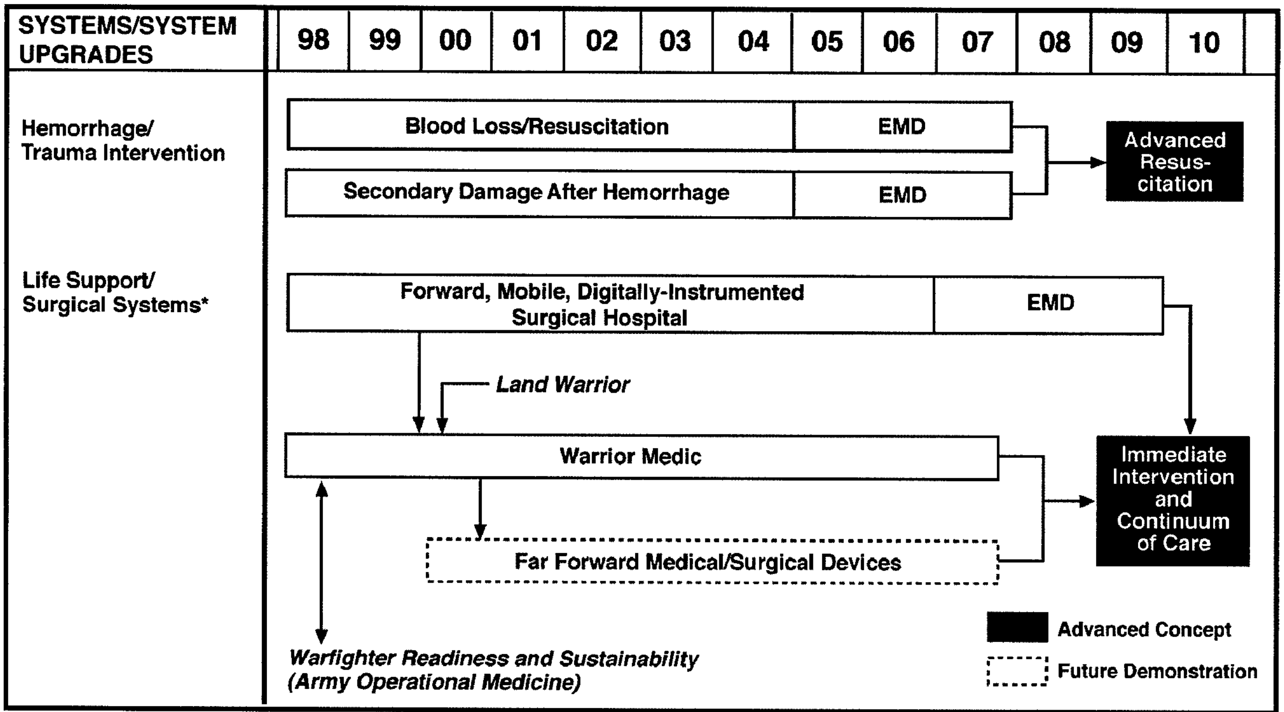
Multiagent Vaccines for Biological Threat Agents TD (1998–02). Vaccine candidates will be demonstrated that will concurrently provide protective immune response against a range of biological threat agents. Combination vaccines offer an approach to immunization that reduces the number of injections, minimizes required medical support, and lowers costs. Recombinant DNA vaccine technology offers the possibility of combining gene products from multiple agents into a single delivery vehicle. Candidate vaccine technologies to be assessed will include naked DNA technologies (as discussed above) and a replicon system. The latter is a vectored system in which portions of the pathogen genes are combined with a portion of viral DNA that allows the bioengineered DNA to be introduced into cells by the normal viral mechanisms and replicated a single time, after which it is eliminated. *Supports:* Multiagent Protective System.

c. Combat Casualty Care Demonstrations

Systems supported within this functional area are hemorrhage/trauma interventions and life support/surgical systems. Hemorrhage/trauma interventions are a family of products intended for use immediately after injury to enhance resuscitation through effective prevention or limiting of hemorrhage, and modulation of the secondary organ damage that results from hemorrhage or other major trauma. Life support/surgical systems are a family of medical devices, software, and associated medical knowledge that will enable the projection of advanced life support and surgical care with the force, and will enable maintenance of critical care through evacuation to CONUS. The modernization roadmap for combat casualty care is shown in Figure III–14.

Blood Loss/Resuscitation TD (1993–04). This demonstration will provide information and transition products to development to enhance capabilities for control of and resuscitation from hemorrhage. This will include the use of commercially available local hemostatic agents, improved thawed or fresh blood preservatives, a field-portable fluid infusion-warming device for the battlefield, an improved platelet preservative or platelet substitute, and a second generation plasma substitute. *Supports:* Advanced Resuscitation.

Secondary Damage After Hemorrhage TD (1993–04). This demonstration will reduce the complications resulting from massive blood loss or major injuries, including measures to minimize irreversible damage during potentially prolonged evacuation. This will include a pharmacological intervention capable of blocking the early



*Technology demonstration also will lead to telemedicine technology insertions.

Figure III–14. Roadmap—Combat Health Support: Combat Casualty Care

steps in development of brain or spinal cord injury that occur secondarily to trauma, a pharmacological intervention that will reduce ischemia/reperfusion injury, intervention that will prevent or reduce trauma-induced immunosuppression and related sepsis, intervention that interrupts the immunological and biochemical events leading to cell death and organ failure after hemorrhage or major trauma, and intervention for far-forward use that reduces the metabolic demands of casualties. *Supports:* Advanced Resuscitation.

Forward, Mobile, Digitally Instrumented Surgical Hospital TD (1996–06). This includes the development of the advanced surgical suite for trauma casualties (ASSTC) mobile hospital and systems for casualty management. The ASSTC will allow for surgical intervention in far-forward areas. *Supports:* Immediate Intervention and Continuum of Care.

Warrior Medic TD (1997–07). This demonstration seeks to integrate various medically oriented, advanced sensor technologies with data integration, calculation, and decision algorithms for the individual soldier, and route the communications through the computer common to all 21st century land warriors (21 CLW). The approach is to develop medical overlays to the tactical computing/communicating capability already under development, to assess injury prognoses, and to compare post-injury to pre-injury data. *Supports:* Immediate Intervention and Continuum of Care.

Far-Forward Medical/Surgical Devices TD (1993–07). This demonstration includes the life support for trauma and transport (LSTAT), low-temperature sterilization system, self-contained ventilator, electrochemical sterilization system, and far-forward suction apparatus. *Supports:* Immediate Intervention and Continuum of Care.

d. Army Operational Medicine Demonstrations

Systems supported within this functional area are performance sustainment, physiological status modeling, and protection criteria. A pri-

mary objective of Army operational medicine demonstrations is the transition of physiological data, models, and algorithms to materiel developers and policy makers to enhance medical readiness and sustainability during deployments. These include technical insertions to Land Warrior for real-time command consultation, furnishing real-time intelligence on warfighter readiness, sustainability, and recovered capability; biomedical and performance damage risk criteria and models ensuring that soldier health and performance are not degraded by their own equipment; and identification of nutritional, pharmacological, and training strategies ("skin-in" interventions) to sustain performance in the face of operational stressors. The modernization roadmap for Army operational medicine is shown in Figure III–15.

Continuous Operations (CONOPS) Nutrition and Metabolic Requirements TD (1992–02). This demonstration will include identification of physiological limitations and approaches to extend these limitations during stressful and intensive continuous operations; determination of how to prepare and restore muscle and liver energy stores and how to deliver the optimal metabolic fuels to the soldier to prevent degradation in physical and cognitive performance (e.g., combinations of hormones, drugs, creatine, specific amino acids, carbohydrate drinks); identification of neurotransmitter precursors (e.g., tyrosine

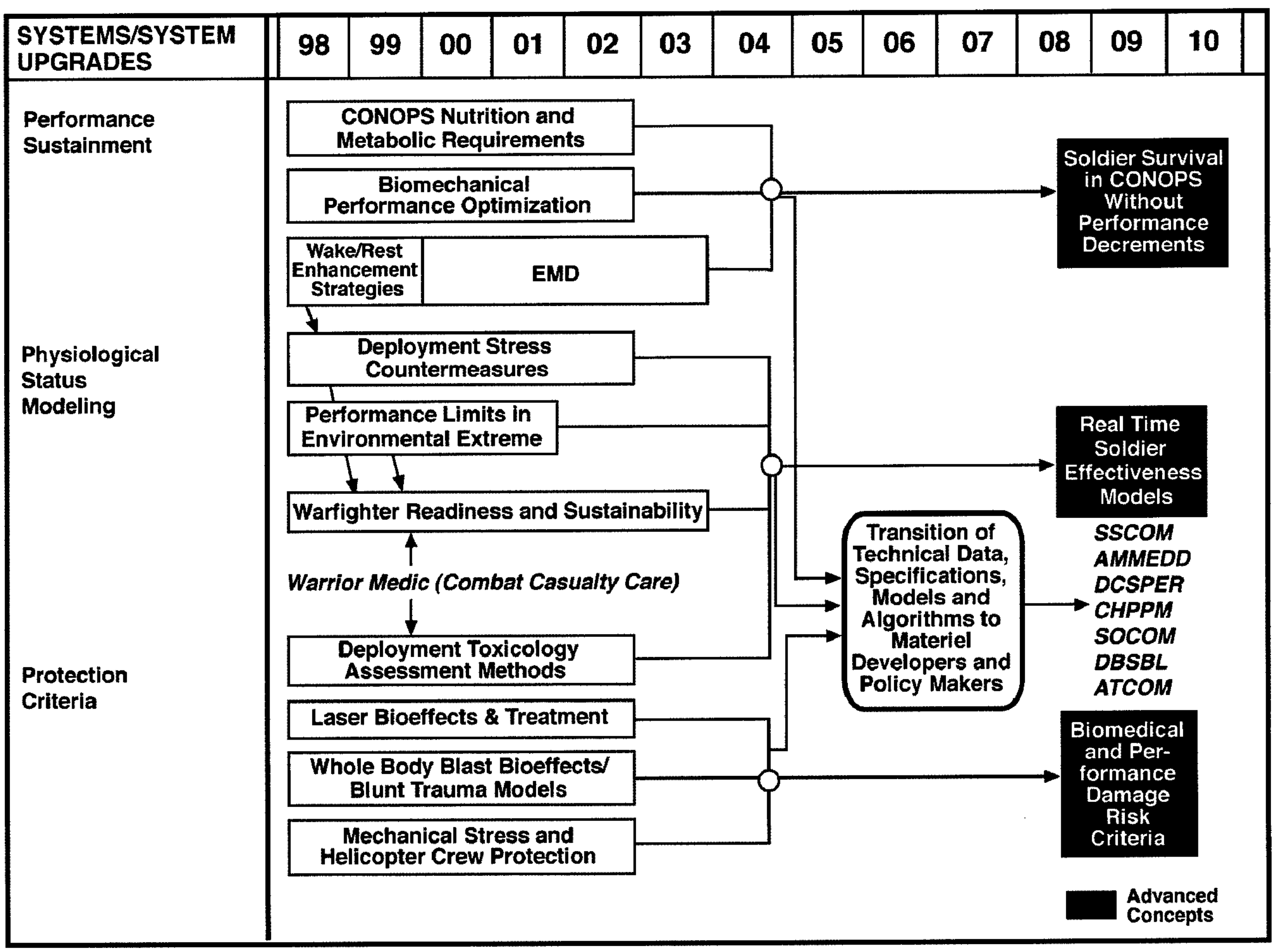


Figure III–15. Roadmap—Combat Health Support: Army Operational Medicine

food bar) or enhancers (e.g., slow-release caffeine) to sustain soldier cognitive function during stressful and demanding operations in adverse environments; and assessment of the feasibility of enhanced physiological recycling of body water, nitrogen, and minerals to sustain performance and lean mass in isolated adverse environments with minimal resupply. Information will transition to Soldier Systems Command ration developers, the Army Medical Department Center and School (AMEDD C&S), and dismounted battlespace battle laboratories (DBSBLs). *Supports:* Soldier Survival in CONOPS Without Performance Decrements

Optimization of Biomechanical Performance TD (1992–02). This demonstration will include: determination of soldier physical characteristics (e.g., strength performance and distribution of muscle mass) and ideal equipment characteristics for materiel designed to fit the soldier (e.g., load carriage systems, body armor, combat boots) to optimize physical health and performance; development of specialized physical training programs to enhance performance capabilities and reduce injury of soldiers in specific tasks (e.g., feasibility of neck and back strengthening to accommodate helmet-supported equipment in repetitive jolt environments); identification of factors involved in bone and muscle remodeling during intensive new training; and development of strategies to enhance strength capabilities and reduce stress fractures and other musculoskeletal injuries during training. Information will transition to combat developers, TRADOC, and Soldier systems command. *Supports:* Soldier Survival in CONOPS Without Performance Decrements.

Wake/Rest Enhancement Strategies TD (1992–99). The efficacy of pharmacological and behavioral interventions to counteract the effects of inadequate restorative sleep and to enhance soldier vigilance and performance during sustained and continuous operations will be demonstrated. Efficacy of new compounds to induce sleep, enhance the restorative value of sleep (e.g., the sleep induction and rapid reawakening system), and resynchronize body rhythms following rapid deployment across multiple time zones (e.g., melatonin) will also be demonstrated. Specifications will be developed for new measurement devices to provide rapid, reliable, and inexpensive means for assessing a soldier's level of mental fatigue and alertness (e.g., actigraphy, brain wave activity). Efforts will also improve guidance for individual, aircrew, and other unit performance as a function of sleep/wake rest cycles. *Supports:* Soldier Survival in CONOPS Without Performance Decrements.

Deployment Stress Countermeasures TD (1992–02). This research will provide the means to reduce stress casualties in future deployments by fielding information and biomedical products to counteract the effects of operational stress on military performance, including means to predict, prevent, assess, and treat battle stress casualties. Methods will be developed to give human dimension teams the capability to provide commanders with statistically valid information on unit stress levels within 72 hours of data collection, and give recommendations for use in operational planning, focused command intervention, and focused intervention by combat stress control teams. This information will transition to the AMEDD C&S and the DBSBL. *Supports:* Real-Time Soldier Effectiveness Models.

Performance Limits in Extreme Environments TD (1992–01). Models will be developed and validated to predict the effects of heat, cold, high altitude, hydration, nutritional status, clothing, and individual equipment on military performance in extreme operational environments. These models will be based on real physiological and psychological data collected during training, as well as operational deployments and advances in the understanding of human responses to multiple stressors. The models will be integrated into command consultation systems in conjunction with the Warfighter Readiness and Sustainability research effort to provide commanders with models for battlefield planning enabling them to "own the environment." New performance criteria will be developed for medical screening based

on visual and auditory requirements on the battlefield. *Supports:* Real-Time Soldier Effectiveness Models.

Warfighter Readiness and Sustainability TD (1996–03). Specifications, physiological models, and algorithms will be developed for a family of wear-and-forget noninvasive soldier sensors that together provide an information system for commanders on the physiological readiness of their own soldiers (e.g., alertness, hydration status, unit integrity). Physiologic sensors connected through a wireless body local area network will be used to establish databases and algorithms for soldier norms and to identify the edge of the health and performance envelope in extreme operational environments. These data will be organized and reduced through a system of knowledge engineering to refine predictive models and to identify the minimal sensor set that will be necessary and compatible with the 21 CLW and follow-on programs. Telemetric transmission of basic medical information from individual soldiers will be made available to commanders in concise form to enhance battlefield situational awareness, and this will form a continuum that transitions to the medic following casualty detection, with telemedicine linkages to far-forward medical assets for early triage of casualties. *Supports:* Real-Time Soldier Effectiveness Models.

Deployment Toxicology Assessment Methods TD (1998–02). Simple, rapid, and integrated hazard assessment and toxicant exposure tools will be developed, based on biosentinel species and bioassays that are durable in field use. The initial emphasis is on complex mixtures of chemicals with neurotoxic effects that immediately threaten military performance in deployed soldiers. Near-real term bioassays methods will transition to more advanced electronic "canaries" and a family of individual soldier bioelectronic sensors that will provide early warning against health and performance hazards. *Supports:* Real-Time Soldier Effectiveness Models.

Laser Bioeffects and Treatment TD (1992–02). This research will provide a database of ocular bioeffects for harmful laser frequency/power mixes and guide development of more effective field protection against laser systems. More effective treatments of laser eye injury will be demonstrated, and drugs and medical equipment to assist in treatment of laser eye injury will be identified for fielding. Information will be transitioned to the AMEDD C&S. *Supports:* Biomedical and Performance Damage Risk Criteria.

Whole Body Blast Bioeffects/Blunt Trauma Models TD (1992–02). A damage risk criteria model for auditory and nonauditory effects of blast will be validated, which will provide scientifically based criteria to support safe fielding of high-powered weapons systems. A finite elements model of blunt trauma will also be developed, which will extend the blast model to provide valid health risk probabilities associated with kinetic nonlethal weapons (e.g., stun grenades, rubber bullets), including torso, head, and extremity injury predictions. *Supports:* Biomedical and Performance Damage Risk Criteria.

Mechanical Stress and Helicopter Crew Protection TD (1992–02). New safety criteria and countermeasures to biomechanical hazards in the man–machine interface for operational combat crews will be demonstrated, based on head injury impact models and spine compression from vertical impacts typically encountered in helicopter crashes and in repetitive jolt in military vehicles and tanks. A jolt and repeated impact model of neck injury will be validated to improve the safe design of helmet-mounted equipment. *Supports:* Biomedical and Performance Damage Risk Criteria.

5. Relationship to Modernization Plan Annexes

To support the Combat Health Support modernization annex of the AMP, new generations of medical systems and products will be tested for technical feasibility and operational utility. Primary emphasis will be placed on capabilities to

minimize casualties through improved protection and prevention, as well as to reduce treatment time for soldiers incapacitated by disease or injury. The relationship of the Combat Health Support S/SU/ACs and other AMP annexes is shown in Table III–22.

Table III–22. Correlation Between Combat Health Support S/SU/ACs and Other AMP Annexes

	System/System Upgrade/Advanced Concept	Modernization Plan Annexes									
		Combat Maneuver	C^4	IEW	Fire Support	Tactical Wheeled Vehicles*	Logistics	Aviation	NBC	Training	Space
System/ System Upgrade	Infectious Disease Pharmaceuticals	●							○		
	Infectious Disease Vaccines	●							○		
	Infectious Disease Applied Medical Systems	●							●		
	CW/BW Casualty Management	●							●		
	CW Prophylaxes and Treatments	●							●		
	BW Countermeasures	●							●		
	Hemorrhage/Trauma Intervention	●					●				
	Life Support/Surgical Systems	●	○	○			●	○	○		○
	Performance Sustainability	●									
	Protection Criteria	●		○	○	○		●			
	Physiological Status Modeling	●	○	●						○	○
Advanced Concept	Medical Prevention and Treatment of Malaria	●							○		
	Medical Prevention of Diarrheal Diseases	●							○		
	Medical Prevention of Dengue Fever	●							○		
	Early and Rapid Disease Threat Assessment	●							●		
	CW/BW Casualty Management System	●							●		
	Full-Spectrum Chemical Protection	●							●		
	Multiagent Protective System	●							●		
	Advanced Resuscitation	●					●				
	Immediate Intervention and Continuum of Care	●	○	○			●	○	○		○
	Soldier Survival in Continuous Operations Without Performance Decrements	●									
	Biomedical and Performance Damage Risk Criteria	●		○	○	○		●			
	Real-Time Soldier Effectiveness Models	●	○	●						○	○

* See Combat Manuever Annex.
● System plays a significant role in the modernization strategy
○ System makes a contribution to the modernization strategy

K. NUCLEAR, BIOLOGICAL, AND CHEMICAL

Weapons of mass destruction, chemical, biological, and nuclear arms will be a major concern for the U.S. forces in the foreseeable future.

General Dennis J. Reimer
Army Chief of Staff

1. Introduction

Any nation with the will can turn its legitimate medical, biotechnology, and chemical facilities to the development of a formidable offensive biological or chemical warfare capability. With the necessary resources, a nation can develop an offensive nuclear warfare capability. The sale of technology and loss of control over weapons of mass destruction (WMD) in various world regions can greatly accelerate the acquisition of WMD programs and weapons. The Tokyo, Japan, subway incident underscores the potential for terrorist use of nuclear, biological, and chemical (NBC) materials. Proliferation overall increases the asymmetric threat of WMD being employed against the United States and its allies during contingency operations.

In response to congressional interest in the readiness of U.S. NBC warfare defenses, Title XVII of the National Defense Authorization Act for FY1994 (Public Law 103–160) required DoD to consolidate management and oversight of the CB warfare defense program into a single office within the Office of the Secretary of Defense and to execute oversight of the program through the Defense Acquisition Board process. The public law designated the Army as the executive agent for coordination and integration of the program and consolidated NBC warfare defense training activities at the U.S. Army Chemical School. Funding for all NBC defense research, development, and acquisition is now consolidated within OSD. Individual service requirements and programs are now consolidated into a true joint, integrated strategy.

This section of the *Army Science and Technology Master Plan* reflects the technology strategy from the perspective of future joint service requirements. The strategy herein is consistent with the AMP, the *Joint Service NBC Modernization Plan*, the *Joint Service NBC Defense RDA Plan*, and the *DoD CB Defense and Nuclear Technology Area Plan*. The Army program in smoke/obscurants is not a part of the joint CB defense program but is included herein as a traditional part of the Army NBC defense mission area.

The primary function of the NBC mission area is to provide U.S. forces with the capability to detect, identify and survive in an NBC environment, and to effectively sustain mission operations with minimal casualties and equipment degradation. In addition, the mission area provides electro-optical obscuration technology and material to screen U.S. assets from enemy precision-guided weapons and reconnaissance, surveillance, and target acquisition (RSTA) for EO countermeasures; and to provide obscuration that allows achievement of military objectives while ensuring force protection and survivability and conservation of combat power. The technology investment in support of these objectives is covered below.

Table III–23 represents the link between NBC S/SU/ACs and Army modernization objectives as well as the capabilities each provides.

2. Modernization Strategy

The NBC modernization strategy reflected in this chapter represents the emerging joint NBC defense strategy in detection, protection, and decontamination, and the Army strategy in smoke/obscurants. The joint NBC detection modernization strategy is focused on point detection for biological agents and remote detection and early warning both chemical and biological agents. Efforts in decontamination and individual protection, recently at a low level, are being increased in recognition of their role in sustainment of the forces and increased mobility. Collective protection efforts remain significantly

Table III–23. NBC System Capabilities

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
DETECTION							*Chemical* Chemical early warning contamination monitoring system that quantifies, ranges, and maps Miniature chemical detector Chemical water monitor *Biological* Biological early warning up to 50 km Biological point detection plus ID system	*Chemical* Long-range chemical imaging detector for aircraft, UAVs, and high-altitude aircraft *Biological* Generic biodetection and ID of asymptomatic levels Rapid automated biodetection ID of bioagents at increased sensitivities (1 ACPLA)
System/System Upgrade								
Chemical Detectors		●	○		○			
Biological Detectors		●	○		○			
Advanced Concept								
Chemical Detectors		●	○		○			
Biological Detector		●	○		○			
PROTECTION & SURVIVABILITY							Integrated respiratory protection: communication, vision, and compatibility with weapon sights Reduced physiological burden and mission degradation Increased confidence in CB protective equipment Improved entry/exit of collective protected combat vehicles Advanced integrated filtration with environmental support systems Regenerable filtration system tailored to host system Reduced logistic support Continuous filtration tailored to light vehicles	Residual life indicator for filters Regenerable filtration (vapor and particulate)
System/System Upgrade								
Individual Protection	●	●				●		
Collective Protection	●	●				●		
Advanced Concept								
Individual Protection	●	●				●		
SUSTAINMENT							Decontamination downtime reduced Less labor intensive	All agent decontamination Decon without water Less labor intensive decon Rapid, self-decon coatings Imaging detector to highlight contaminated areas and decon efficacy Corrosivity eliminated Environmentally safe
System/System Upgrade								
Decontamination	●	●				●		
Advanced Concept								
Decontamination	●	●				●		

Table III–23. NBC System Capabilities (continued)

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
COUNTER RSTA/ DECEPTION							Screening, camouflage, and decoy capabilities in visible, IR, and MMW ranges Logistically acceptable Environmentally safe	Smart weapons defeat capability EO marker for combat ID DEW defeating obscuration
System/System Upgrade								
Smoke/Obscurants		●	○	○	●			
Advanced Concept								
Smoke/Obscurants		●	○	○	●			

● Provides significant capability ○ Provides some capability

reduced and refocused to provide far term capabilities. A capability to identify significant improvements in decontamination is being maintained. Smoke/obscurants technologies are being pursued to expand the regions of the electro-optic spectrum that can be selectively obscured. A significantly smaller effort is being pursued to spin off nonlethal weapons concepts from relevant corporate technology capabilities.

Protecting the force is paramount in the joint NBC defense strategy. Early detection and warning is key to this strategy by providing situational awareness and the capability of U.S. forces to counter any NBC threat. Chemical and biological detection systems, fully integrated in the digital battlefield, will enable battlefield commanders to detect NBC warfare agents at operationally significant levels and immediately activate protective or avoidance measures. Decision aids and planning tools will assist commanders at all levels. They will be designed to allow non-NBC staffs to evaluate NBC situations and allow for timely and effective decisions. The goal of protection is to isolate forces and weapons systems from NBC agents using individual and collective protection systems. Personnel protection will consist of nonmedical, respiratory, and whole body protection that will allow forces to operate at near normal levels of effectiveness while in protective posture. Integrated environmental control and longer life NBC filtration will meet the increasing need for collective protection for vehicle crew compartments, shelters, and command posts. When NBC contamination cannot be avoided, decontamination systems and point detectors will be used to restore personnel and units rapidly to near normal operating capability. New decontamination technologies and systems will reduce the hazard of decontamination operations on personnel, equipment, and the environment; minimize the logistics burden; and decrease the restoration time. CB modeling and simulation technologies are being enhanced to assess doctrine, training, and materiel operating in an NBC environment, to provide equipment design parameters, and to serve as a real-time decision aid for battlefield commanders. The following goals define the NBC defense strategy:

- Provide rapid field biodetection and identification capability.
- Extend range and coverage of chemical and biological standoff and early warning detection capabilities.
- Integrate chemical and biological sensors and systems with the digitized battlefield.

- Maintain current protection capability while reducing degradation associated with individual protective equipment.
- Develop continuous, regenerable collective protection filtration systems integrated with environmental controls requiring minimal logistics.
- Develop effective, low environmental impact decontamination systems that do not damage contaminated surfaces.
- Enhance CB modeling and simulation capabilities to allow concept evaluations, hazard assessment, and realistic training for the CB-contaminated battlefield.

Smoke and obscurants provide a potent combat multiplier by increasing the effectiveness of certain weapons systems, countering enemy RSTA efforts, conserving effective combat power and supporting deception operations. The thrust of the smoke/obscurant technology strategy is:

- Enhance the capability of smoke/obscurants to defeat enemy RSTA capabilities by selectively dominating the electromagnetic spectrum, thus allowing the maneuver commander to control the maneuver space.
- Enhance the survivability of the individual soldiers and vehicles through the development of improved multispectral self-defense obscuration systems.

Modernization efforts will be implemented through horizontal integration of NBC capabilities into major weapon systems. NBC materiel acquisition will be conducted via technology insertions, product improvements, and advanced concepts. Integration efforts such as these will ensure significant gains in operational survivability and mission sustainment at modest incremental costs. The joint NBC modernization strategy is postured to meet the challenges facing U.S. forces in the 21st century.

3. Roadmaps for CB Defenses and Smoke Obscurants

Figures III–16 and III–17 are the roadmaps for CB defense and smoke/obscurants, respectively. Table III–24 summarizes the demonstrations and systems found in these figures. This strategy emphasizes technology demonstrations incorporated into the front end of critical development programs. These demonstrations will significantly reduce development risk, verify the system integration of advanced technologies, and facilitate technology insertions, where possible.

The NBC defense program emphasizes detection, protection (individual and collective), decontamination, and modeling and simulation. The roadmap for NBC defense is shown in Figure III–16.

The detection portion of CB defense is divided into two categories: chemical detectors and biological detectors. Both remote early warning and point detection technologies are being pursued for chemical and biological detectors. The goal of CB detection is to provide a real-time capability to detect, identify, locate, map, and quantify the presence of all CB warfare agent threats at levels below hazardous levels and to disseminate this information rapidly. Current emphasis is on multiagent sensors for point biological agent detection and remote early warning chemical and biological detection. In the near term, a number of individual sensors are being developed while detection technology matures. In particular, a miniaturized chemical vapor point detector and an automated biological point detector and identifier will be available. Far-term objective technologies focus on the integration of chemical and biological detection into a single sensor suite. Technology emphasis is on detection sensitivity and specificity across the entire spectrum of CB agents (programmable for emerging threats), system size and weight, reduction of logistics support requirements and O&M costs, detection range, and signature and false alarm rates. Integration of CB detectors into various platforms (vehicles and aircraft) and C^4I networks constitutes the ultimate focus of this technology area.

Table III–24. NBC Demonstration and System Summary

Advanced Technology Demonstration	Technology Demonstration
Integrated Biodetection (OSD funded)	**CB Defense**
	Joint Biological Universal Detection System
Advanced Concept Technology Demonstration	Joint Service Warning and Identification LIDAR Detector
	Chemical Imaging Sensor
	Joint Service Agent Water Monitor
Airbase/Port Biological Detection (includes chemical detection add-on)	Joint Warning and Reporting Network
	Liquid Surface Detection
Joint Biological Remote Early Warning (proposed)	Joint Service General-Purpose Mask
	Joint Service Aviation Mask
	Joint Service Chemical Ensemble
	Joint Service Collective Protection
	Joint Service Sensitive Equipment
	Joint Service Chemical and Biological Decon
	Generic Decon
	Smoke/Obscurants
	Millimeter Wave Screening
	Direct Fire Smoke
(See Volume II, Annex B, for additional information)	Vehicle Engine Exhaust Smoke
	Electro-Optical System Marking Smoke

System/System Upgrade/Advanced Concept

System	Superior Decon Solution
Joint Service Warning and ID LIDAR	Large Area Smoke System
Joint Service Agent Water Monitor	Vehicle Engine Exhaust Smoke System
Joint Biological Remote Early Warning System	**Advanced Concept**
Joint Service General Purpose Mask	Wide Area Detector
Joint Service Aviation Mask	Liquid Surface Detector
Joint Service Mini Decon	Joint Radiac System
Joint Service Sensitive Equipment	Joint CB Universal Detector
Joint Service Fixed Site Decon	Next-Generation General-Purpose Mask
Direct Fire Smoke	Next-Generation Protection Assessment Test System
Electro-Optical System Marking Smoke	Joint Chemical Ensemble II
System Upgrade	Aircraft Interior Decon
Joint Warning and Reporting Network P^3I	Enhanced Fixed Site Decon
Joint Biological Point Detection System	Multispectral Smoke Pot
Joint Biological Universal Detection System	Multispectral Projects Directed-Energy Neutralization System
Joint Chemical Ensemble	
Joint Collective Protection Improvement Program	Multispectral Canopy Smoke

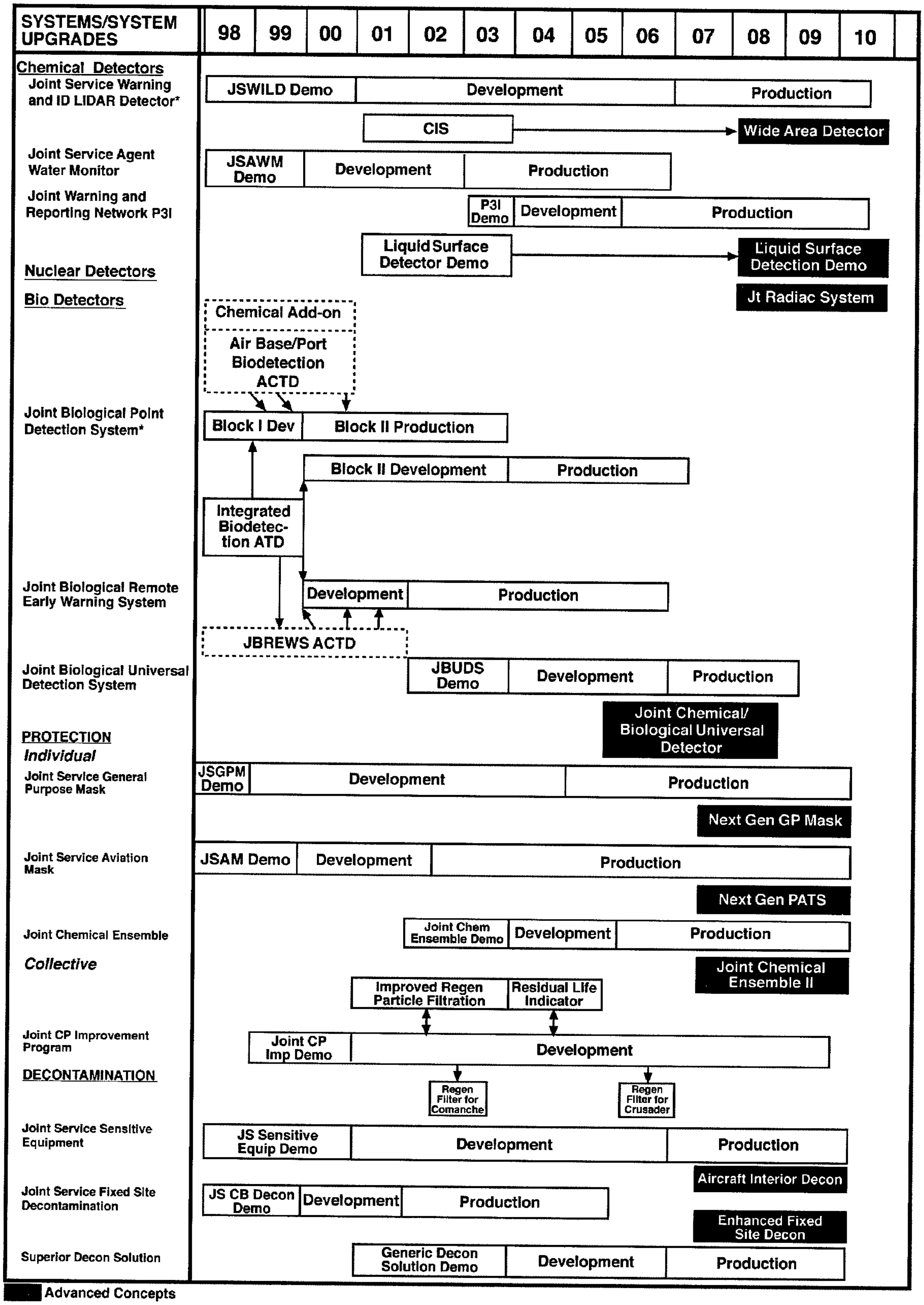


Figure III–16. Roadmap—Nuclear, Biological, and Chemical Defense

The NBC protection area covers technology efforts to provide NBC protection for the individual warfighter as well as enclosures where groups of personnel require collective protection from the contaminated environment. The goal of eye, respiratory, and percutaneous protection technology efforts is to develop the next generation eye and respiratory protection equipment and clothing ensembles for the 21st century warfighter. This equipment will afford protection against current and future threats, minimize mission degradation and physiological impacts, and improve system integration and compatibility. Collective protection technology is focused on developing air purification systems for buildings, shelters, vehicles, aircraft, and ships that must operate in NBC warfare agent-contaminated battlefield conditions. Current efforts are directed at regenerative vapor and particulate filtration technologies, deep-bed impregnated carbon, residual filter life indicators, and novel single pass filter designs and materials to reduce overall cost, size, weight, and flow resistance to facilitate widespread application.

The goal for decontamination technologies is to develop effective, environmentally low impact CB decontamination systems to neutralize or break down toxic materials without damaging the contaminated surface or affecting the performance of the equipment being decontaminated. This area includes decontamination of personnel, individual equipment, tactical combat vehicles and equipment, sensitive electronics, cargo areas of aircraft, seagoing vessels, and critical assets in fixed sites. Due to increased user interest, funding in this area has been enhanced. Studies will focus on the use of supercritical carbon dioxide, ozone, sorbents, solution decontamination, and enzyme-based systems.

Modeling and simulation technologies are being investigated to provide enhanced command evaluations, to integrate sensor data, and to permit realistic training and simulation of the CB battlefield environment. The information generated will provide decision aids to commanders to allow tradeoffs among tactical options as well as assessment of joint services doctrine, training, leadership, organization, materiel, and warfighter performance during and after a CB attack. Modeling and simulation technologies will be used to evaluate the battlefield value-added potential of developmental and conceptual NBC systems and will become an integral part of every development program and every phase of the acquisition cycle. A current thrust is to incorporate terrain, mesoscale meteorology, and objects such as tanks, ships, or buildings into CB-effects, hazard-assessment models and to incorporate these models into new and existing combat simulations such as ModSAF and distributed interactive simulations (DIS).

Joint Biological Remote Early Warning System (JBREWS) ACTD (Proposed) (1998–01). The objective of this ACTD is to evaluate the utility of remote early warning for BW point attacks against U.S. forces and to develop operational procedures and doctrine associated with that capability. The ACTD will enhance the overall biological force protection system in a theater by providing sensors significantly farther upwind (therefore closer to the BW agent release point) in much greater density than current biological detection systems. This demonstration will exploit the inherent power of networked sensors and revolutionize our current approach to warning and reporting of BW attacks. The ACTD will demonstrate a BW early warning network that is organic to a CINC tactical unit and connected to a warning and reporting system to alert forces downwind promptly of BW agents. The ACTD will leverage mature and low-risk biological detection technologies from the DoD counterproliferation initiative and technology base community, as well as the Department of Energy's Chemical Biological Nonproliferation program. Extensive simulation will be conducted in parallel to evaluate the utility of the remote early warning system during all phases of warfighting operations. *Supports:* JBREWS.

Integrated Biodetection ATD (1996–99). The Integrated Biodetection ATD will demonstrate

point detection and remote early warning of biological agents using two state-of-the-art technologies. In addition, multiyear 6.2 technology-based efforts are being carried out in both areas to support and ensure the successful demonstration of the ATD technologies in FY96–99. The ATD will focus on point biosensors that incorporate automated DNA diagnostic technology to identify biological agents with the highest known degree of specificity and sensitivity, in addition to increasing current reliabilities, stabilities, and response times of fielded and near-term P^3I biosensors. These state-of-the-art biological identification devices are planned for incorporation into the Joint Biological Point Detection System (JBPDS) as next-generation biosensors. A rapid, real-time biological aerosol warning system using small, micro-ultraviolet (UV) laser-based, fluorescent particle counters will also be demonstrated. Its purpose is to provide an early warning of a biological aerosol cloud threatening high value battlefield assets. The key to the demonstration is to show the technologies in a unified effort in a battlefield exercise providing detection and warning of biological agents before forces are exposed, thus reducing casualties. *Supports:* JBPDS and JBREWS.

Airbase/Port Biological Detection ACTD (1996–00). The objective of this ACTD is to evaluate the military utility of an airbase or port perimeter biological detection capability and to develop operational procedures associated with that capability. An additional objective is to provide a residual capability adequate to detect, alarm/warn/dewarn, and identify against a BW attack on an airbase or port facility. The airbase or port residual capability will consist of a perimeter biological detection capability, laboratory agent identification capability, dewarning procedures, C^4I connectivity with base NBC reporting, oronasal protection, and biological sensor decontamination procedures and capability. This ACTD will also include a chemical add-on capability that will utilize mature and available technology (passive IR spectrometry and ion mobility spectroscopy) to detect and identify automatically chemical threat agents in near real time (less than 30 seconds). Additionally, this chemical add-on will provide the CINCs a capability to network legacy and emerging biological and chemical detectors, and will produce automated warnings and reportings for enhanced battlefield visualization and force protection as defined in *Joint Vision 2010. Supports:* JBPDS and JBREWS.

Joint Biological Universal Detection System (JBUDS) TD (2002–03). The JBUDS will be the universal detector to the armed forces that fully integrates both point and remote sensors into one detector. This demonstration will feature miniaturized, multitechnology-based, fully automatic (in manned or unmanned mode), all-agent-capable (generic) detection with automatic warning and reporting linked to the theater C^4I system. This capability will provide the commander an all encompassing chemical and biological assessment of the battlefield. *Supports:* JBPDS.

Joint Service Warning and Identification LIDAR Detector (JSWILD) TD (1998–00). This demonstration will emphasize joint service operation with shipboard testing and airbase defense demonstrations. Previous work has demonstrated the feasibility of using IR light detection and ranging (LIDAR) to detect vapors of nerve agents and also shown great promise in the detection of large droplets of nerve agents. In addition, the detection of aerosol particles of all sizes and compositions will be demonstrated and sensitivities determined for each application. All service interferences will be identified and introduced into the existing model for inclusion into the pattern recognition detection algorithm during subsequent development. The goal of this demonstration is to determine capabilities and limitations for each possible mission (ship defense and fixed site defense). *Supports:* Airbase Defense and Shipboard Warning, JSWILD, and Joint Service Nuclear, Biological, and Chemical Reconnaissance System (JSNBCRS).

Chemical Imaging Sensor TD (2001–03). This sensor will expand the capability of current passive interferometry and signal processing to

allow long-range chemical imaging. The sensor will be capable of detecting known chemical agents and can be programmed to detect other militarily significant spectral data. It will also provide a visual display of the hazard area. Extended detection range capability will be provided for use on aircraft and high-altitude reconnaissance systems. The program will use design and performance data developed in Project Safeguard. *Supports:* Wide Area Detection.

Joint Service Agent Water Monitor (JSAWM) TD (1998–99). The JSAWM will demonstrate both an in-line (USAF) and a portable batch water test capability. JSAWM will be capable of detecting chemical agents below the revised U.S. Army Surgeon General's requirements for chemical agents and also be able to detect a range of waterborne biological agent contamination down to parts per million. The system will rapidly evaluate water and provide near-real-time alert if water becomes contaminated so that immediate action can be taken to prevent ingestion by warfighters. *Supports:* In-Line Water Monitor (USAF) and Agent Water Monitor (U.S. Army Quartermaster).

Joint Warning and Reporting Network (JWARN) P^3I TD (2003). The JWARN P^3I will build from the capabilities of off-the-shelf integration efforts of the interim JWARN program. This first step includes sensor links, a hazard prediction tool, and an automated NBC warning and report system. The P^3I version will demonstrate seamless integration into the future digitized "common picture" of the battlefield. Included will be decision aid support modules and automation tools that provide a shared situational awareness of the hazard and allow real-time NBC defense synchronization. Advanced call-back capabilities for split-based operations and a high-resolution digitized mapping capability are being pursued. *Supports:* JBREWS, JBPDS, and Battlefield Digitization.

Liquid Surface Detection TD (2001–03). This program will demonstrate an active/passive hybrid system for detection and identification of chemical agent liquid surface contamination. This effort will culminate in the development of a system for reconnaissance, contamination avoidance, and decontamination effectiveness evaluation. *Supports:* reconnaissance (air and ground), standoff detection (vehicle and fixed site), alarms/monitors, and warning and reporting.

Joint Service General-Purpose Mask (JSGPM) TD (1997–98). A variety of advanced respiratory protection concepts are being investigated for application to a joint service eye/respiratory protection system for ground use and possibly for use in Army aviation applications. The general-purpose mask will provide protection against current and future CB threats, reduced physiological and psychological burden and resulting mission degradation associated with individual protection equipment, and improved integration with future soldier systems (e.g., weapons sighting systems, night vision equipment, helmets, helmet-mounted displays) and joint service requirements. Technology efforts will focus on improved filter design and filtration media, lens design and materials, agent resistant faceblank materials, and reduced bulk/logistics burden. Advancements in protection and performance testing to support assessment to anticipated standards are included in these efforts. *Supports:* Joint Service General-Purpose Mask and FXXI LW.

Joint Service Aviation Mask (JSAM) TD (1998–99). The joint services are supporting this technology effort to develop a protective mask system for high-performance aviation and rotary-wing pilots. The effort will focus on consolidation of requirements from a series of high-performance aviation and helicopter mask systems, and development of performance specifications sufficient to support EMD initiation in FY00. Various mask technologies and designs will transition to the JSAM program as they become available. *Supports:* Joint Service Aviation Mask and Air Warrior.

Joint Service Chemical Ensemble TD (2002–03). A variety of materials and materials technologies are being investigated to provide

fully integrated percutaneous protection against chemical and biological agents into the warrior's battledress ensemble. Integrated CB percutaneous protection will eliminate the need for a separate battledress overgarment. To accomplish this, protective materials must be resistant to agents without increasing the physiological burden (e.g., heat stress, moisture buildup) normally associated with wearing individual protection equipment/ensembles. Selectively permeable fabrics that will allow heat and moisture to escape while not allowing agents to permeate (i.e., selective permeable membrane technology) will provide the soldier with enhanced percutaneous protection over carbon-impregnated materials used in the current battledress overgarment. *Supports:* Joint Service Lightweight Integrated Suit Technology (JSLIST) P^{3}I.

Joint Service Collective Protection TD (1998–99). Several advanced CB filtration concepts will be evaluated to prove feasibility in implementing improved filtration technologies into various combat system applications. Technologies investigated will include regenerable vapor and particulate filtration systems, catalytic systems, improved sorbents, improved nuclear and biological particulate filtration media, and residual vapor filter life indicator. Advanced filtration concepts demonstrate reduced size and weight potential, improved filtration capability, elimination of filter change out (except at scheduled maintenance periods), and integration with power and environmental control systems. *Supports:* Advanced Field Artillery System (AFAS)/Future Armored Resupply Vehicle (FARV) and Comanche, Crusader, Advanced Amphibious Assault Vehicle (AAAV), and NBC Collective Protection Systems (Advanced Deployable Collective Protection (CP) for Fixed Sites, Advanced Lightweight Collective Protection System).

Joint Service Sensitive Equipment TD (1998–00). This demonstration addresses two requirements. The first will consist of using a closed-loop recirculating supercritical carbon dioxide system to remove chemical and biological materials from small sensitive equipment items and components. A second system using ozone as an oxidizing agent will be demonstrated as a means to decontaminate and detoxify chemical and biological agents in interior spaces containing electronic components. These systems will provide additional capability to the user. They will eliminate the need for protective status while performing maintenance operations, render contaminated individual equipment and small electronics reusable after prior contamination, and provide the capability to decontaminate the interior spaces of aircraft, tanks, ships, and other vehicles. *Supports:* Joint Service Sensitive Equipment Decontamination System and Aircraft Interior Decon System.

Joint Service Chemical and Biological Decontaminants (JSCBD) TD (1998–99). The objective of this demonstration is to provide the joint services with a decontaminant to reduce and eventually eliminate requirements for decontamination solution 2 (DS2). This decontaminant should be environmentally acceptable and be useful for applications where the use of DS2 is currently forbidden. Several commercially available CB decontamination systems have been identified and have inspired the interest of several joint service user groups as a potential interim solution to the DS2 problem. This demonstration will evaluate the effectiveness of these potential nondevelopmental items and provide the user community with performance data. *Supports:* Modular Decon System, Joint Service Mini-Decon System, Superior Decon Solution, and Joint Service Fixed Site Decon.

Generic Decontamination Solution TD (2001–03). This demonstration will evaluate the effectiveness of a new generation of decontamination materials that are nontoxic, material compatible, and environmentally safe. Technologies investigated will include high-capacity surfactants, improved sorbent systems, reactive organic solutions, dry powder formulations, and enzymatic-based systems in a variety of carrier systems. Materials should be suitable for a variety of surfaces and applications, ultimately

replacing DS2 and any interim decontaminant chosen to reduce reliance upon DS2. *Supports:* Superior Decon Solution, Modular Decon System, Joint Service Mini-Decon System, and Joint Service Fixed Site Decon.

In response to the proliferation of increasingly sophisticated RSTA capabilities throughout the EM spectrum, the smoke/obscurant strategy capitalizes on technologies capable of providing multispectral screening. These environmentally and logistically acceptable multispectral materials will counter enemy RSTA activities in broader ranges of the EM spectrum for self-defense, large area coverage, and projected applications. The roadmap for smoke/obscurants is shown in Figure III–17.

Millimeter-Wave Screening TD (1999–00). This demonstration will determine the feasibility of an MMW obscurant generating system in preventing threat radars from observing, acquiring, targeting, and tracking friendly targets. The module will expand the capability of the current M56 large area smoke generator, which screens only the visual and IR bands. Aerosol technology, chemical dispersion techniques, and dissemination mechanisms will be exploited. *Supports:* Smoke/Obscurants (M56 P^3I).

Direct Fire Smoke TD (2001–02). This demonstration will develop the technology required to support direct fire obscurant munitions. Low-cost, nontoxic, environmentally friendly materials, effective in all spectral regions of military interest, will be investigated with an eye toward

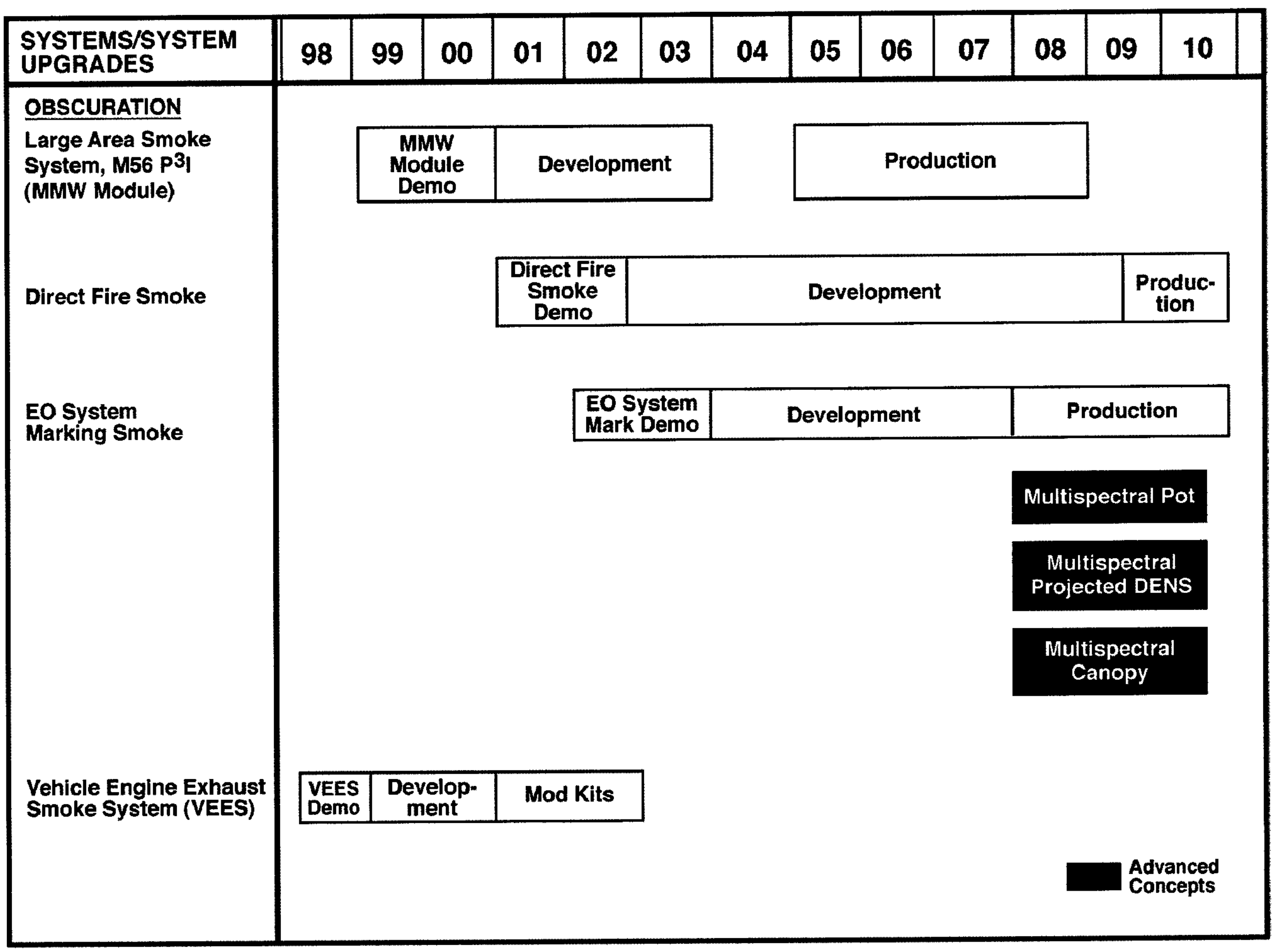


Figure III–17. Roadmap—Smoke/Obscurants

performance consistent with a volume-constrained application. Creative packaging will be investigated that will minimize environmental impact. *Supports:* Smoke/Obscurants (Direct Fire Smoke).

Electro-Optical (EO) System Marking Smoke TD (2002–03). This demonstration will consist of a personal smoke grenade that will release a material detectable only by a mid- or far-IR sighting device. The grenade is intended for ground force use as a signaling device to mark landing and drop zones. It also has application for pilot rescue missions and combat identification. This demonstration will explore cryogenics, exothermic reactive materials, and reaction control techniques. *Supports:* Smoke/Obscurants (EO System Marking Smoke).

Vehicle Engine Exhaust Smoke (VEES) System TD (1998). This demonstration revives the old diesel fuel-based VEES made ineffective when the M1 Abrams went to JP8. It will be packaged as a modification kit to existing M1A1 Abrams platforms. It enhances unit survivability by screening movement, concealing position, and defeating enemy visual and near-IR target acquisition systems such as laser designators and laser range finders, especially in military OOTW and during peacekeeping operations. Current prototype incorporates a swing-away mount, facilitating maintenance. *Supports:* Smoke/Obscurants (PM Abrams SEP).

4. Relationship to Modernization Plan Annexes

Table III–25 shows the correlation between the NBC S/SU/ACs and the other modernization plan annexes that they support.

Table III–25. Correlation Between NBC S/SU/ACs and Other AMP Annexes

System/System Upgrade/Advanced Concept		Modernization Plan Annexes: Force Structure*	Combat Maneuver	C^4	IEW	Fire Support	Space & Missile Defense	Tactical Wheeled Vehicles*	Logistics	Aviation	Combat Health Support	Training	Space
System/ System Upgrade	NBC Individual Protection		○					●	●	●	○		
	NBC Collective Protection		○	●			○	●	●	●	●		
	Chemical Detectors	○	●	○	○		●	●	○	○	●	○	
	Biological Detectors	○	●	○	○		●	●	○	○	●	○	
	NBC Decontamination		●					○	○	○	●		
	Smoke/Obscurants		○		○		●	○	●			○	
Advanced Concept	NBC Individual Protection		○					●	●	●	○		
	Chemical Detectors	○	●	○			●	●	○	○	●	○	○
	Biological Detectors	○	●	○			●	●	○	○	●	○	
	NBC Decontamination		●					○	○	○	●		
	Smoke/Obscurants		○		○		●	○	●			○	

* See Combat Manuever Annex.
● System plays a significant role in the modernization strategy
○ System makes a contribution to the modernization strategy

L. AIR AND MISSILE DEFENSE

Not the cry, but the flight of the wild duck, leads the flock to fly and follow.

Chinese proverb

1. Introduction

As the 21st century approaches, air and missile defense must be ready to meet the challenge of the evolving air and missile threat while continuing to support force projection operations in major regional contingencies, protect the United States in coordination/cooperation with joint air defense systems, and execute military operations other than war missions. The air and missile threat is often the single greatest risk to the successful conduct of force projection operations, particularly during early entry and decisive operations. With many nations acquiring technologically advanced, highly lethal weapons such as ballistic missiles, our air and missile defense force can expect to face a much more diversified threat in the future. Threat capabilities of other nations beyond the year 2000 will require that the air and missile defense force be capable of dominating battlespace to achieve decisive victory by winning quickly with minimal casualties.

The mission of air and missile defense is to protect the force and selected geopolitical assets from aerial attack, missile attack, and surveillance. To meet its mission requirements and counterthreat capabilities, the air and missile defense force must be a strategically deployable, highly mobile, and versatile force, trained and equipped to go to war anywhere in the world on short notice; it must be highly lethal and capable of battlefield survival. The air defense mission includes national missile defense (NMD) of the continental United States and antisatellite defense, as well as theater missile defense (TMD), which protects the force from theater missile attacks. Both NMD and TMD are addressed in Volume II, Annex D.

Successful execution of future operations will require increased emphasis on planning and conducting joint and multinational operations. The capabilities of many weapons and forces must be integrated to achieve the operational commander's air defense objectives.

2. Relationship to Operational Capabilities

To achieve the required operational capabilities, a balanced materiel development and demonstration strategy must be followed. Multifaceted technology base efforts have been initiated across the full spectrum of tactical through strategic requirements. Initiatives emphasize survivable target acquisition (both passive and active) and positive identification; cost-effective fusion of multiple sensor/processor modules into automated target acquisition and fire control suites; multiple missile guidance modes against the reactive threat; high-energy, insensitive propellants and alternate propulsion concepts; missile seeker upgrades to integrate advanced fuzing techniques and smart focal plane arrays; hit-to-kill technology; mobile, lightweight, and increased firepower; dispersed, distributed, survivable C^2 and supporting communications, and an integrated training architecture that fully exploits the materiel capability. Table III–26 shows the correlation between air and missile defense SU/ACs and the Army modernization objectives, and displays in general terms the operational capabilities for air and missile defense SU/ACs.

3. Modernization Strategy

The air and missile defense and TMD modernization plan annexes detail a disciplined approach to providing air and missile defense support to both theater and maneuver forces. The air and missile defense modernization strategy focuses on the following objectives:

- Achieve near leakproof TMD this decade.
- Address the full threat spectrum.
- Respond to warfighting doctrine.
- Maintain a technological advantage.

Table III–26. Air and Missile Defense System Capabilities

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
KILL SYSTEMS							Missile defense	
System Upgrade							High firepower	
Patriot PAC3	○	●	●	○	○	○	Expanded engagement envelope	
							Hit to kill	
Bradley Stinger Fighting Vehicle-Enhanced (Linebacker)	○	●	●	○	○	○	Increased mobility/survivability	
							3D surveillance and tracking	
							Low radar cross section targets	
							Highly mobile	
							Target in clutter	
Advanced Concept								IR CCM
Stinger Block II	○	●	●	○	○	○		Improved lethality against helicopter
								360-degree coverage

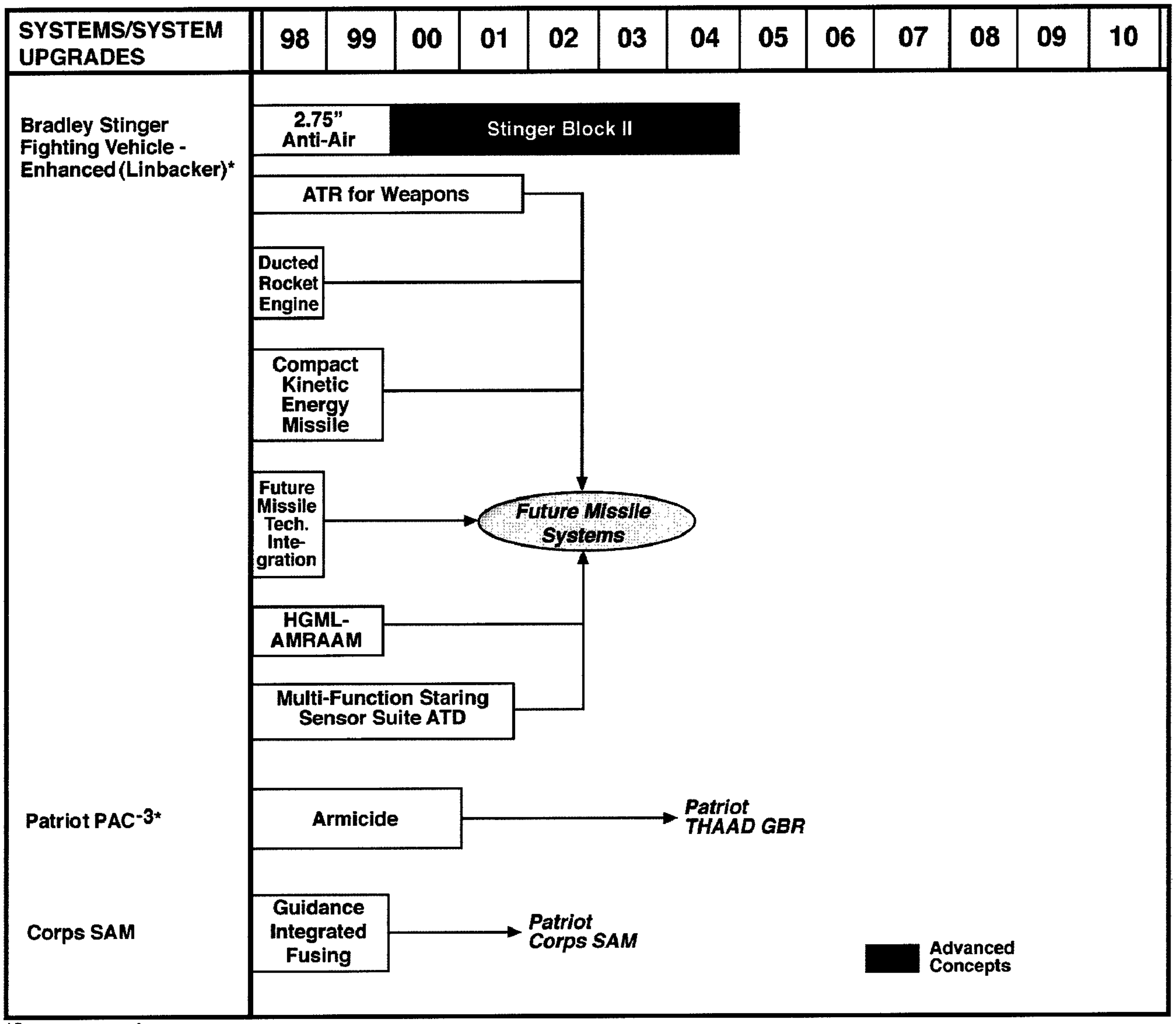
● Provides significant capability ○ Provides some capability

4. Roadmap for Air Defense Artillery

Table III–27 presents a summary of demonstrations and systems found in the air and missile defense roadmap (Figure III–18). Modernization of air and missile defense depends upon the development of these key systems for air defense coordination.

Table III–27. Air and Missile Defense Demonstration and System Summary

Advanced Technology Demonstration	Technology Demonstration
Multifunction Staring Sensor Suite (see Mounted Forces)	Guidance Integrated Fuzing
	2.75-Inch Antiair
	Ducted Rocket Engine
	Future Missile Technology Integration
	Compact Kinetic Energy Missile
(See Volume II, Annex B, for additional information)	High-Mobility Ground-Launched AIM–120 Advanced Medium-Range Air-to-Air Missile
	Armicide
	ATR for Weapons
System/System Upgrade/Advanced Concept	
System Upgrade	**Advanced Concept**
Patriot PAC3	Stinger Block II
Bradley Stinger Fighting Vehicle—Enhanced (Linebacker)	



*System upgrade.

Figure III–18. Roadmap—Air Defense Artillery

a. Advanced Technology Demonstrations Leading to Modernization of Air Defense Artillery Units

Air defense artillery systems consist of a complementary mix of weapons, sensors, and command and control systems. air and missile defense modernization focuses on SU/AC developments and their associated demonstrations. The MFS^3 ATD will have a major impact on the air defense mission. Additionally, the mission area will derive benefits from many other efforts, such as the RFPI ACTD, the Target Acquisition ATD, and the BCID ATD.

Multifunction Staring Sensor Suite (MFS^3) ATD (1998–01). The MFS^3 ATD will integrate multiple advanced sensor components including staring infrared arrays, multifunction laser, and acoustic arrays. In support of air defense, it will demonstrate the capability for automated surface-to-surface, surface-to-air, and air-to-ground search, acquisition, and noncooperative identification. More detailed information can be found in Section III–G, "Mounted Forces" (above). *Supports:* Bradley Stinger Fighting Vehicle—Enhanced (BSFV–E) (Linebacker).

b. Technology Demonstrations Leading to Modernization of Air Defense Artillery Systems

The following are primarily focused on the air and missile defense mission area.

2.75-Inch Antiair TD (1997–99). The objective of the 2.75-Inch Antiair TD is to provide a comprehensive upgrade to the Stinger missile system through the incorporation of an advanced imaging infrared seeker to enable the engagement of hostile helicopters in clutter at extended ranges (two to three times current capabilities). This demonstration will go beyond the current concept development program of a form-factored seeker with commercial breadboard-type signal processing electronics by demonstrating the ability to package the signal processing electronics in 2.75-inch-diameter space. In addition, signal processing algorithms for target detection, tracking, and IR CCM will be developed and demonstrated via hardware in the loop simulations, ground tests, and captive-carry tests. This system will maintain compatibility with existing Stinger launchers and retain Stinger's excellent capability against fixed-wing aircraft. *Supports:* Forward-Area Air Defense (FAAD) Stinger Block II and all launch platforms.

Ducted Rocket Engine (DRE) TD (1996–98). This TD is discussed in detail in Section III–N, "Fire Support."

Future Missile Technology Integration (FMTI) TD (1994–98). This technology demonstration is discussed in detail in Section III–D, "Aviation" above.

Compact Kinetic Energy Missile (CKEM) TD (1996–99). This technology is discussed in detail in Section III–G, "Mounted Forces" (above).

ATR for Weapons TD (1998–01). This technology demonstration is discussed in detail in Section III–D, "Aviation" (above).

High-Mobility Ground-Launched AIM–120 Advanced Medium-Range Air-to-Air Missile (AMRAAM) (HMGL–AMRAAM) TD (1996–99). The primary focus for this technology demonstration will lead to a low-cost, highly mobile air and cruise missile defense capability based on the robust capabilities of the joint Air Force/Navy/USMC AIM–120 AMRAAM. This concept will integrate this extremely capable digital fire-and-forget missile onto a highly mobile Avenger-based heavy HMMWV ground launch platform. Army cueing for the systems will be provided by the AN/MPQ–64 ground-based sensor (GBS) (or any other 3D sensor), and remote fire control will be managed with the simplified handheld terminal unit. The Marine Corps will use their continuous wave acquisition radar for cueing and the remote terminal unit for management of remote fire control operations. The AIM–120 AMRAAM launched from an HMMWV-based system provides a medium-range, high-rate-of-fire missile with the multiple simultaneous target engagement capabilities needed to fill the gap between Stinger and Patriot. The mix of short (Stinger) and medium (AIM–120) range missiles will provide both the IR and the RF guidance and homing needed to counter the evolving cruise missile and UAV threats. *Supports:* AIM–120 AMRAAM, RFPI ACTD, and Current and Future Missile Systems.

Guidance Integrated Fuzing TD (1995–99). The objective of this program is to develop guidance integrated fuzing techniques for MMW, active-homing seeker systems in air defense missiles, utilizing a mix of target signature measurements, target backscatter modeling, and end-game modeling. This effort will also provide algorithms for integrated guidance and fuzing to track high-speed targets from the munition to achieve accuracy for warhead kills. In addition, near-far field target signatures from an MMW, monopulse instrumentation radar will be collected. It is expected that this effort will generate high-fidelity target models to support highly accurate guidance integrated fuzing simulations to validate robust system designs. *Supports:* Patriot Advanced Capability (PAC3) and Corps Surface-to-Air Missile (Corps SAM).

Armicide TD (1997–00). The Armicide TD will demonstrate a concept designed to serve as an adjunct for antiradiation missile (ARM) defense to the major air defense systems such as Patriot and the theater high altitude area defense (THAAD) ground-based radar (GBR). Armicide will use the organic air defense system radars to provide the fire control to engage the ARM target. Thus, the need for providing an expensive counterarm sensor is avoided. Armicide consists of the following main components that are currently within the realm of engineering implementation or available with minor modifications: (1) a medium-caliber, command-guided smart munition that does not require an expensive homing seeker; (2) two rapid fire conventional launchers, whose design and technology are in use by all services, as well as internationally; (3) a fire control processor/transmitter; and (4) the host radar (Patriot and GBR) that will provide target and interceptor tracking information to the fire control unit of the radar. *Supports:* Patriot, THAAD GBR.

c. Benefits to Air Defense Artillery Systems

Benefits to the air defense mission area that may be derived from ATDs, STOs, and advanced concepts are as follows:

- New search and track capabilities which could be adapted into air defense's multi-sensor capabilities.
- Improved integration of sensors and fire control systems providing faster slew-to-cue capabilities for air defense weapons.
- Propellant and guidance movements that may be incorporated into air defense weapons to provide dead zone and self-protection coverage.
- Combat identification enhancements to ensure higher accuracy of positive identification of hostile and friendly targets, therefore reducing possibility of fratricide.
- Communication enhancements improving the vertical and horizontal sharing of critical battlefield information and increasing the accuracy and volume of data being shared.
- Survivability enhancements that will lower the susceptibility of air defense sensors to ARMs and will decrease existing air defense systems vulnerability to indirect fire.
- Fuzing improvements that will lead to higher probability of kills of both conventional targets and weapons of mass destruction.
- Digitization of the battlefield.

5. Relationship to Modernization Plan Annexes

It is important that air and missile defense modernization and related technology base program efforts exhibit a linkage with AMP annexes in other mission areas. This linkage is important for decision makers when prioritizing all of the Army's modernization efforts. Table III–28 portrays the linkage of Air Defense Artillery SU/ACs and other AMP annexes.

Table III–28. Correlation Between Air and Missile Defense S/SU/ACs and Other AMP Annexes

System/System Upgrade/Advanced Concept		Aviation	IEW	Close Combat Light*	C^4	Mounted Forces*	TMD**
		Modernization Plan Annexes					
System	Corps SAM	○	○		○		●
System Upgrade	Patriot Advanced Capability		○		○		●
	Bradley Stinger Fighting Vehicle—Enhanced (Line-backer)				○	●	○
Advanced Concept	Stinger Block II	○		○	○		○

* See Combat Maneuver Annex.
** See Space & Missile Defense Annex.
● System plays a significant role in the modernization strategy
○ System makes a contribution to the modernization strategy

M. ENGINEER AND MINE WARFARE

Have you ever been in a minefield? ... All there has to be is one mine and that's intense.

General H. Norman Schwarzkopf, USA (Ret.)

1. Introduction

The U.S. Army is facing a changing threat with varied degrees of sophistication as it enters the 21st century. Given this uncertain threat, the engineer and mine warfare (EMW) mission area continues to play a key role as a critical member of the combined arms team. Recent military operations have demonstrated the critical need for a robust EMW mission area, which is vital to the combined arms team and combat service support elements being able to fulfill their future military role.

The EMW mission area consists of the five major battlefield functions of mobility, countermobility, survivability, sustainment engineering, and topographic engineering. Each function is critical to conducting successful operations throughout the operational continuum, whether fighting a major regional conflict or providing military assistance in operations other than war. Applying technological advancements to modernize these functions enhances the combined arms commander's ability to conduct opposed entry, sustained land combat, and OOTW to achieve a decisive victory. This section focuses on funded EMW S&T programs that provide systems and system upgrades in support of combat maneuver modernization. Only systems and system upgrades identified in the Combat Maneuver annex to the AMP, of which EMW is a part, and advanced concepts with planned 6.3 technology demonstrations of potential future systems are addressed in this section.

2. Relationship to Operational Capabilities

Table III–29 shows the relationship between the EMW S/SUs and each of the TRADOC battlefield dynamics. It also details some of the operational capabilities provided by these S/SUs.

3. Modernization Strategy

The Combat Maneuver annex to the AMP provides the blueprint for equipping engineer forces into the next century. It embraces the Army's modernization vision—land force dominance—by contributing to the five Army modernization objectives.

- *Project and Sustain.* The assessment and construction or reconstruction of ports, airfields, roads, and other infrastructure to project forces rapidly and consistently and maintain logistical forces.
- *Protect the Force.* Construction of structures to protect critical C^2, weapon systems, and logistics nodes by camouflage, concealment, or bunkerage.
- *Win the Information War.* Provide engineer-related force level information, standard hard copy and digital maps, map substitute imagery, battlefield visualization products, and other types of terrain data, giving commanders a realistic view of the battlefield. Information and products must be readily available, rapidly updated, and quickly manipulated or tailored. Real-time electronic distribution to all elements of the force will increase leader battlefield awareness and allow commanders to operate inside their opponent's decision cycle.
- *Conduct Precision Strike.* Utilization of accurate electronic terrain data for display and tactical exploitation to obtain precise location data of both the target and the shooter. Engineer assessment of conventional weapons effects against hard structural targets will ensure correct munition-to-target linkage. This will lead to improved effectiveness and precision of weapon system fires and total dominance of the deep battle.

Table III–29. EMW System Capabilities

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
MOBILITY								Advanced biological explosives detection
System								
Ground Standoff Mine Detection System		○	●	○	●		Advanced image processing	Advanced time domain EM induction
							Real-time data transfer	Ultra wideband holographic radar
							Detection for heavy and light forces	
Mine Hunter/Killer		●	●	○	●		Multisensors	
							Robust sensor fusion	
							Advanced antitank	
							Computer fire control	
							Combined detection and neutralization capability	
							Teleoperation capability	
							Unexploded ordnance detection	
							Rapid breaching and mine unexploded ordnance (UXO) clearance	
Lightweight Airborne Multispectral Countermine Detection System		●	●	○	●		Lightweight airborne standoff detection capability	
							Advanced staring FPAs	
							Advanced sensors (multihyperspectral, passive, polarization)	
							Advanced electronic stabilization advanced ATR	
Advanced Concept								Advanced tracking
Standoff Scatterable Mine and Munition Detection		●	●	○	●			Advanced handoff to radar to determine range, trajectory, and location
Advanced Mine Detection Sensor System		●	●	○	●			Advanced signal processing and ATR algorithms

Table III–29. EMW System Capabilities (continued)

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
SURVIVABILITY *System Upgrade* Low-Cost, Low-Observable Technologies		●		○	●		Improved visual, IR, and radar signature suppression Low-cost mobile signature suppression Improved chemical agent resistant coating IR suppressive coating Integrated active/passive signature control in UV, visible IR, and RF bands Tunable countermeasures	
TOPOGRAPHIC ENGINEERING *System Upgrade* Digital Topographic Support System/Quick-Response Multicolor Printer	●	●	●	●	○	○	Rapid map or map substitute products Battlefield environment effects Real-time creation, update, and dissemination of digital topographic databases Integrated decision aids	

● Provides significant capability ○ Provides some capability

- *Dominate the Maneuver Battle.* Enhancing the tactical mobility of friendly maneuver forces and impeding the mobility of threat forces to provide commanders both protection and maneuverability necessary to dominate battlespace.

The EMW modernization strategy relies on continuous modernization as a key concept. The acquisition approach emphasizes investment in S&T programs leading to ATDs, targets of opportunity, battle laboratory experiments, AWEs, and the Joint CM ACTD. Technological advances will be incorporated more often into systems via upgrades versus entirely new systems.

Of the EMW battlefield mission areas, mobility and survivability are currently receiving a new focus in S&T due to the ever-increasing mine threat. Effective and responsible mine warfare obstructs the mobility and survivability of opposing forces and creates conditions favorable to the mine employer without inflicting needless casualties on noncombatants. Mine warfare constitutes a significant element in armed conflict at all levels of intensity and is critical to early entry forces who may be overmatched. The intelligent minefield (IMF) ATD will enhance the antiarmor lethality of the early entry force, cue fires beyond line-of-sight, and provide the potential to revolutionize maneuver. IMF can not only be turned off to provide one-way obstacles, but should be able to augment friendly maneuver forces by performing screen and guard missions autonomously. Mines are cheap, lethal, psychologically disruptive, and readily available, and they will be encountered on all future battlefields. The result is that relatively cheap mines employed quickly and in quantity can immobilize a powerful force.

Inexpensive, land mines can destroy multimillion dollar weapon systems. The future outlook is even more ominous, with the evolution of new smart mines. Microelectronics will soon take mines to new levels of lethality. The countermine shortfall is particularly worrisome because it strikes at the heart of Army's doctrine of rapid movement and surprise to win quick decisive victories.

4. Engineer and Mine Warfare Roadmaps

Table III–30 presents a summary of the S/SU/ACs, TDs, ATDs, and ACTDs found on the EMW roadmap shown in Figure III–19.

Engineers enhance friendly freedom of maneuver by detecting, bypassing, breaching, marking, and reporting mines and other obstacles, crossing gaps, providing combat roads and trails, and performing forward aviation combat engineering (FACE) operations. S&T programs focus on integrating countermine capabilities through live and simulated experiments, maintaining Army and Marine Corps enhanced mobility, survivability, situational awareness, and agility to the force commander as a result of integrating countermine technology with C^4I. The technologies include sensors, IR, microwave, multispectral, seismic and acoustic decoys, explosive neutralization, information processing, robotics, and other emerging technologies.

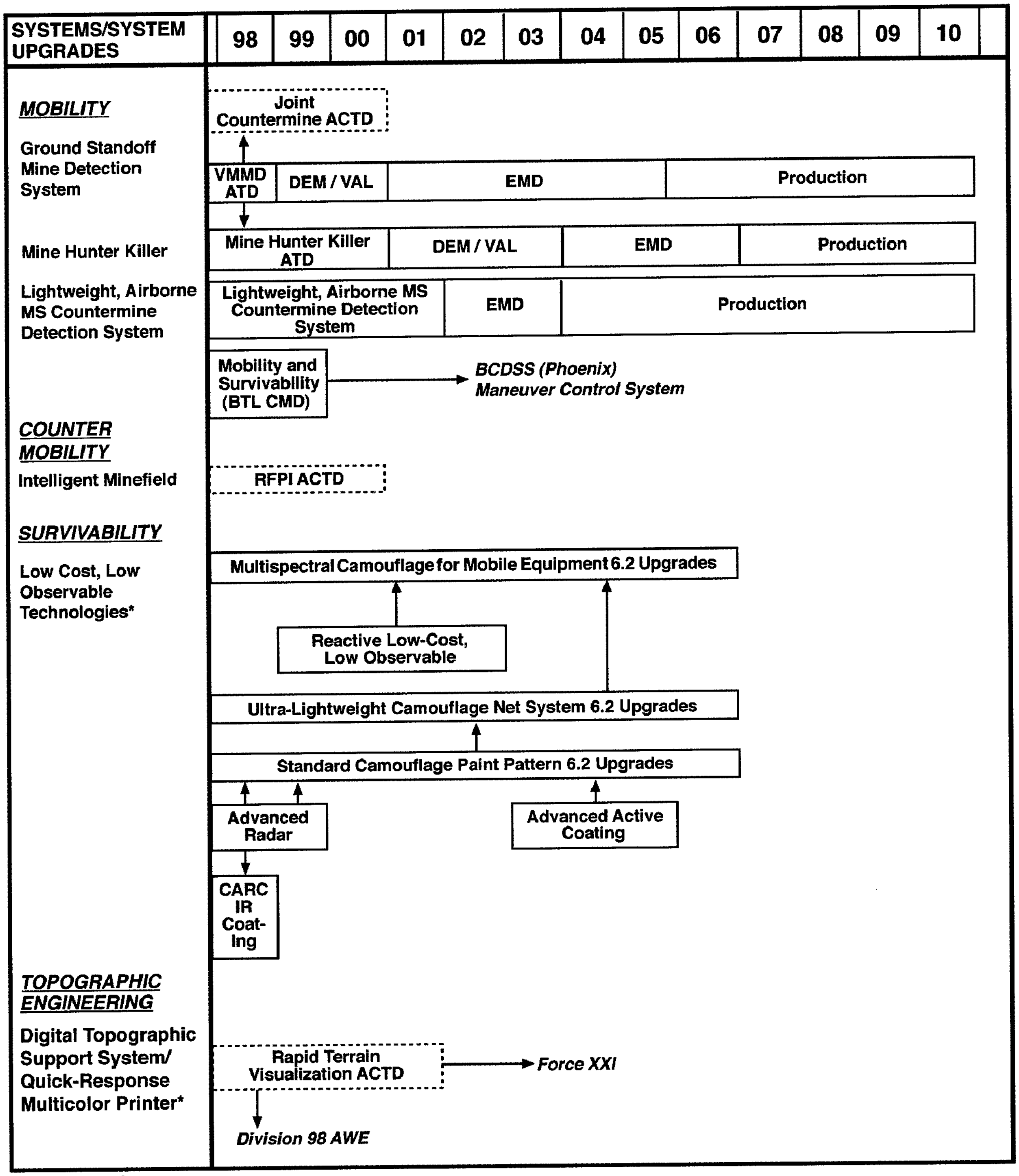
Joint Countermine (CM) ACTD (1995–00). This ACTD will demonstrate a seamless amphibious and land warfare countermine operational capability from sea to land by coordinating Army, Navy, and Marine Corps technology demonstrators, prototypes, and fielded military equipment.

Demonstration I, successfully executed in 4QFY97, focused on near-shore capabilities of assault, reconnaissance, breaching, and clearing with emphasis on in-stride detection and neutralization of mines and obstacles. The Army was the lead for Demonstration I. It included joint Army–Marine Corps technology demonstrations in mine detection technology for the Army's future close-in man-portable mine detector, with the capability to detect both metallic and nonmetallic mines (handheld standoff mine detection system). It also included countermeasures to side-attack mines (off-route smart mine clearance) in support of road-clearing operations. These technologies are applicable to other military uses such as unexploded ordnance and range clearing, duds on the battlefield, and demining.

Table III–30. EMW Demonstration and System Summary

Advanced Technology Demonstration	Technology Demonstration
Vehicular-Mounted Mine Detector	**Mobility**
Mine Hunter–Killer	Mobility and Survivability (Battle Command)
Advanced Concept Technology Demonstration	Lightweight, Airborne Multispectral Countermine Detection System
	Survivability
Joint Countermine	Low-Cost, Low-Observable Technologies
Rapid Terrain Visualization	
(For additional information, see Volume II, Annex B)	

System/System Upgrade/Advanced Concept	
System/System Upgrade	**Advanced Concept**
Ground Standoff Mine Detection System	Low-Cost, Low-Observable Technologies
Mine Hunter/Killer	Advanced Mine Detection Sensors
Lightweight Airborne Multispectral Countermine Detection System	Standoff Scatterable Mine and Munitions Detection
Digital Topographic Support System/Quick-Response Multicolor Printer	
Maneuver Control System	



*System upgrades.

Figure III–19. Roadmap—Engineer and Mine Warfare

Demonstration II, planned for 3QFY98, will emphasize technologies of clandestine surveillance and reconnaissance as described in the FY94 Navy Mine Warfare Plan and will demonstrate the elements of seamless transition of countermine operations from sea to land. The Navy is lead for Demonstration II.

Mobility and Survivability (Battle Command) TD (1995–98). This program will demonstrate decision support applications for mobility, countermobility, and survivability force level information that supports multiple battlefield operating systems. Physics-based algorithms, applicable to all climatic regions, that automate the engineer's efforts to filter, assess, and manipulate data into relevant information for the maneuver commander and staff will be incorporated into obstacle planning software and simplified survivability assessments that will be demonstrated during Task Force XXI AWE and Division XXI exercises. The software suite to be demonstrated will also provide the engineer commander with the ability to execute engineer domain force level command and control. *Supports:* Battle Command Decision Support System (BCDSS) (Phoenix) and Maneuver Control System (MCS).

Vehicular-Mounted Mine Detector (VMMD) ATD (1996–98). The vehicular detector will demonstrate the mounted capability to detect metallic and nonmetallic mines, conventionally or remotely emplaced. The primary operational mode of the VMMD is to detect mines on roads and routes across full vehicular widths so that lines of transportation are kept open. There is no currently fielded vehicular mounted system that can detect both metallic and nonmetallic mines. The ATD will demonstrate in FY98 a system using multiple sensor suites, sensor fusion, and ATR techniques. Sensor fusion will provide for a higher mine detection rate while keeping false alarm rates at an acceptable level. The sensors that will be demonstrated include IR, ground-penetrating radar (GPR), and EM induction detectors. The IR sensors include both 3 to 5-μm and 8 to 12-μm wavelength sensors. These will be currently available sensors with specially developed ATR algorithms. The primary purpose of the IR sensor is to provide a standoff cueing detection capability. The GPR operates in the 13-GHz band that represents a tradeoff between the lower frequencies required for sufficient ground penetration and the higher frequencies needed to achieve spatial resolution for specific targets. Various algorithms are being investigated for use with the GPR approach. The EM induction detection combines traditional metallic mine detection operating features with an innovative concept that combines the induction coils with the GPR antennas in a single search head. *Supports:* Joint Countermine ACTD and Ground Standoff Mine Detection System.

Mine Hunter/Killer (MH/K) ATD (1998–00). The MH/K program will allow the Army to investigate and clear routes and roads through terrain where conventional countermine tools are not desirable and do so at near tactical speeds. The purpose of the MH/K program is to develop an integrated standoff mine detection and neutralization system for installation on any tactical vehicle. The system is intended to neutralize surface laid and buried, metallic and nonmetallic, AT and large AP mines. The MH/K system will consist of a multimode sensor array including forward-looking radar, and FLIR systems with a robust sensor fusion architecture and advanced ATR algorithm suite, a target designation system, a set antimine weapon with computer fire control and articulation, and a stabilized tele-operations kit. The system will detect and destroy mines and unexploded ordnance in a wide path in front of the vehicle at moderate speeds without needing to pause or stop. *Supports:* MH/K and Ground Standoff Mine Detection System P^3I.

Lightweight Airborne Multispectral Countermine Detection System TD (1998–01). This demonstration will utilize novel focal plane array (FPA) and system technologies (3 to 5 μm staring FPAs, passive polarization, multi-hyperspectral imaging, electronic stabilization) to develop a lightweight airborne standoff mine detection capability for limited area (point) detection, lim-

ited corridor route reconnaissance, and detection of nuisance mines along roads. The system will detect buried nuisance mines on unpaved roads and off-route side attack mines, as well as detect surface and buried patterned and scatterable minefields. The system will also have applications to other intelligence-gathering programs requiring increased thermal sensitivity as well as those that would benefit from a wider field of view than supported by a framing FLIR. *Supports:* Tactical UAV.

a. Countermobility

Engineers impede the enemy's freedom of maneuver by disrupting, turning, fixing, or blocking his movement through obstacle development and terrain enhancement. S&T programs are integrating microelectronics, signal processing, and advanced intelligence into a controlled network of mine warfare systems. The Intelligent Minefield S&T program ended in FY97, but continues to support technology developments through participation in the Rapid Force Projection ACTD. To use this future capability and other engineer assets optimally requires the development of software to assist in evaluating the whole picture (environment, intelligence data, assets, capabilities, etc.) to facilitate planning and execution of maneuver operations.

Area Denial Systems TD (1998–01). This program will demonstrate the capability of self-contained, semiautonomous, long-standoff munitions that can defend an area by defeating, disrupting, and delaying vehicles that enter into its battlespace. This system will enhance other weapon systems in a manner similar to that achieved by land mines today, but without the postwar civilian mine threat and the demining problem. *Support:* Unmanned Terrain Domination.

b. Survivability

Engineers reduce friendly force vulnerability to enemy weapon effects through rapid fabrication of protective structures, terrain alteration, and concealment. S&T programs are focused on upgrades to the low-cost, low-observable (LCLO) camouflage systems. These systems provide means for detection and hit avoidance. The upgrades are designed to reduce or eliminate visual, UV, near IR, thermal IR, and radar waveband signatures of mobile and stationary assets. The goal is to counter the highly sensitive reconnaissance, intelligence, surveillance, target acquisition (RISTA) threat sensors, and fused sensors in all parts of the EM spectrum. Signature control will be achieved through integration of passive, reactive, and active low-observable systems.

Field fortifications research is conducted by the Corps of Engineers Waterways Experiment Station (WES) for all of DoD. The focus of these efforts is in design of protective structures to defeat advanced munitions (bunker busters) and unconventional munitions (car bombs), to capture commercial technology, and to identify high-payoff protection techniques.

Low-Cost, Low-Observable (LCLO) System Upgrade TD (1994–06). Demonstrations are scheduled during FY94–00 for upgrades to LCLO systems, including the multispectral camouflage system for mobile equipment, the ultra-lightweight camouflage net system—general-purpose (ULCANS–GP), and the reactive/active standardized camouflage paint pattern (SCAPP). Currently fielded LCLO systems do not counter threat thermal IR sensors. *Supports:* ULCANS–GP, Multispectral Camouflage System for Mobile Equipment, and SCAPP.

c. Sustainment Engineering

Engineers support force sustainment by maintaining, upgrading, or constructing lines of communication and facilities; providing construction support and materials; and performing area damage assessment. Sustainment in the form of infrastructure assessment, generation and allocation of engineer resources required, and visualization technologies will be among the technologies critical in wartime contingency and support and sustainment operations.

d. Topographic Engineering

Topographic engineers provide timely, accurate knowledge of the battlefield and terrain visualization to operational commanders and staffs at all echelons throughout the operational continuum. Knowledge of the battlefield consists of information in narrative or graphic format describing the effects of terrain and climate on military operations. The ability of the commander to visualize the terrain in all climate conditions before the battle will help him to develop dynamic operational plans, as well as to locate, engage, and defeat the enemy with a more agile, synchronized force. Terrain information developed by Army engineers provide the basic terrain reference for land and air forces as well as other DoD and non-DoD agencies.

S&T programs focus on providing terrain database construction or update real-time positioning and navigation determination, realistic physics-based terrain capabilities, geospatial database management, database value-adding for modeling and simulation, and tactical terrain and environment decision aid support. Key to battlefield awareness and crisis response is the development of technologies to support the capability for the rapid production and dissemination of image-based topographic products. Advances in microelectronics, knowledge-based systems, and signal processing techniques make the topographic engineering sciences an extremely dynamic field.

Topographic engineers are working closely with TRADOC battle labs and the user community to demonstrate, evaluate, and refine technological developments and doctrinal topographic support concepts. The digital topographic support system—multispectral imagery systems (DTSS–MSIP) currently fielded to all active duty topographic units provides automated topographic support and imagery exploitation capabilities to the commander. The DTSS/Quick Response Multicolor Printer (QRMP), to begin fielding in FY98, will provide a tactical capability to support the commander further with the latest in topographic technology. The P^3I program will provide periodic increases in functionality, maintaining topographic support at the technological leading edge in capability and in data imagery exploitation.

Rapid Terrain Visualization (RTV) ACTD (1997–01). The RTV ACTD will demonstrate the capabilities required to provide the warfighter level V elevation data, feature data, and imagery over a 90×90 km area in 72 hours. The focus of the RTV ACTD will be on source collection, data generation, and transformation of digital topographic data. These data are the essential foundation for battlefield visualization. Situation databases, integrated on current terrain databases, provide the commander a dynamic, 3D visualization of his battlespace and enhance his mission planning, course of action analysis, and mission rehearsal capabilities. The ACTD will leverage technologies being developed by government and industry. These technologies will be integrated in the JPSD Integration and Evaluation Center (IEC) and analyzed to determine their effectiveness. The ACTD has provided a testbed capability to the XVIII Airborne Corps to ensure continual feedback on the military value of capabilities. Selected capabilities, whose maturity has been demonstrated in the IEC, will be transitioned to the user testbed for evaluation. An objective capability will be delivered to the using unit as leave behind in the year 2000. *Supports:* XVIII Airborne Corps Warfighter Exercises, Force XXI, and Division '98 AWE.

5. Relationship to Army Modernization Plan Annexes

The EMW modernization strategy and related S&T programs are linked with modernization plans in other mission areas. Table III–31 shows the linkage between EMW S/SUs and other AMP annexes.

Table III-31. Correlation Between EMW S/SU/ACs and Other AMP Annexes

	System/System Upgrade/Advanced Concept	Modernization Plan Annexes: Mounted Forces*	Close Combat Light*	Space & Missile Defense	IEW	Soldier Systems	C^4	Aviation	Fire Support
System	Maneuver Control System	○	○				●		
	Ground Standoff Mine Detection	●	●			○	●		
	Mine Hunter/Killer	●	○			○	○		
System Upgrade	Lightweight Airborne Multispectral Countermine Detection System	●	●	○	●		○		○
	Digital Topographic Support System/Quick-Response Multicolor Printer	●	●	○	●		●	○	○
	Low-Cost Low-Observable Technologies	●	○	○	○		○	○	
Advanced Concept	Advanced Mine Detection Sensors	●	●				●		
	Standoff Scatterable Mine and Munition Detection	●	○		○	○	○		

* See Combat Maneuver Annex.
● System plays a significant role in the modernization strategy
○ System makes a contribution to the modernization strategy

N. FIRE SUPPORT

The artillery must be prepared to concentrate a great volume of fire wherever it is needed, at any moment, so as to dominate rapidly any part of the battlefield which might be threatened.

General Charles DeGaulle
The Army of the Future, 1941

1. Introduction

Fire support is the collective and coordinated use of indirect fire, target acquisition data, armed aircraft, and other lethal and nonlethal means against ground targets in support of maneuver force operations. The mission of fire support is to destroy, neutralize, or suppress the enemy with indirect fire and integrate all available means of fire support.

Fire support responsibilities focus on close support fires in support of engaging maneuver units, counterfire (the attack of enemy indirect fire support systems), and interdiction (the attack of enemy laterally and in depth). It includes artillery, mortars, other non-line-of-sight weapons, Army aviation, naval gun fire, close air support, and electronic countermeasures.

2. Relationship to Operational Capabilities

To achieve the required operational capabilities, the fire support S/SU/ACs will provide unique system capabilities that will enhance the commander's ability to meet the dynamic requirements of the battlefield. Fire support capabilities include supporting the ability of early entry operations to deploy rapidly and secure the operational area; providing critical elements of the combat power required to defeat an enemy throughout the depth of the battlefield; supporting the commander's requirement to control the rate and pace of combat activities; supporting critical aspects of the commander's ability to effect operations against opposing forces engaged in combat actions; and providing essential capabilities in the logistics spectrum to support, rearm, and resupply fire support assets required to sustain the soldier on the battlefield (see Table III–32).

3. Modernization Strategy

The *Army Modernization Plan* Fire Support annex provides the direction and focus of our modernization strategy. The cornerstone for the successful implementation of this continuous modernization strategy is our science and technology programs. These programs will focus on system upgrades, new systems, and advanced concepts that will provide quality materiel to commanders that ensure their ability to "fight fire with fire."

4. Fire Support Roadmap

Table III–33 presents a summary of ACTDs, ATDs, and major TDs leading to systems development and upgrade. Modernization of the fire support operating system depends upon the development of these key systems for fire support coordination, close support, counterfire, command and control, and target acquisition, as well as munitions and rockets, and their ultimate fielding as a fire support system-of-systems.

As shown in Figure III–20, S&T efforts focus on:

- Maximization of kill capability.
- Advanced gun/rocket propulsion.
- Automated ammunition handling.
- Integrated fire control and battle management.
- Signature reduction and increased protection.
- Classification, tracking, and identification of ground vehicles.
- Sensors (acoustic and electro-optical) and processing.
- AI and computing technologies.
- Increased battlefield operational mobility.

Table III–32. Fire Support System Capabilities

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
RANGE							Deep fire 20 to 40 km beyond FLOT 54% increase in onboard ammo (60 vs. 39 Paladin) Decision aids 155-mm range from a light-weight system	
System								
Crusader	●	○		○	○	●		
Lightweight 155-mm Towed Howitzer	●	○		○	○	●		
System Upgrade								
ERA Projectile—XM982	●	○		○	○	●		
Advanced Concept								
Guided MLRS	●	○		○	○	●		Increased range or cargo capacity
LETHALITY							Increased rate of fire (12–16 rounds/second) Point target accuracy Robotic and automated rapid ammo handling Increased lethality area 155-mm firepower from a lightweight system	Mobile long-range capability Reduced logistics burden RF energy IFF Top attack surgical kill Increased footprint covers moving targets Improved response time Increased range with self-destructive cargo Precision guidance capability
System								
Crusader	○	●		○	○	○		
Lightweight 155-mm Towed Howitzer	○	●		○	○	○		
System Upgrade								
Multimode Airframe Technology	○	●		●	●	○		
ERA Projectile—XM982	○	●		●	○	○		
Advanced Concept								
Guided MLRS	○	●		●	○	○		
Precision-Guided Mortar Munition	○	●		●	○	○		
ACCURACY							Deep fire 20 to 40 km beyond FLOT Onboard sensors Onboard target acquisition Increased sensor accuracy Increased mobility Munitions classification Decision aids Improved navigation Point target capability at long ranges	
System								
Crusader	○	○		●	●	○		
Lightweight 155-mm Towed Howitzer	○	○		○	○	○		

Table III–32. Fire Support System Capabilities (continued)

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
System Upgrade								
Firefinder P³I		●	○		○	○		
Multimode Airframe Technology	○	●		●	○	○		
ERA Projectile—XM982	○	○		●	●	○		
Advanced Concept								Improved delivery accuracy Man-portable fire control
Precision-Guided Mortar Munition	○	●	○	●	●	○		Top attack surgical kill for U.S. infantry
Guided MLRS	○	●		●	○	○		GPS auto-registration or auto-self-correcting Improved targeting Precision guidance capability
SURVIVABILITY							Autonomous	
System							Real time on target meteorological data	
Crusader	○	●			○	○	Decision aids	
Lightweight 155-mm Towed Howitzer		○			○	○	155-mm range firepower and area coverage with lightweight mobility	
System Upgrade							Doubles range	Reduce time at firing point
Firefinder P³I		○	○	○	○		250% greater survivability Smart weapon ECCM Improved mobility Datalink to TMD	Novel (nonvolatile) propellants Improved ECCM Rapid deployment Route planning and self-defense AI modules Launch to digitized battlefield Fire and forget
Advanced Concept								
Guided MLRS		○			○			

Table III–32. Fire Support System Capabilities (continued)

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
FORCE MULTIPLIER							Based on increased accuracy	
							Less manpower	
System							Commonality of spares	
Crusader	○	○				○	Affordable long-range navigation	
Lightweight 155-mm Towed Howitzer		○				○	155-mm fire power for light forces/	
							Smart weapons	
							Extended range cargo delivery	
							Increased lethality	
System Upgrade								Extended range cargo delivery (40–70 km)
ERA Projectile—XM982	○				○	○		AI
Firefinder P³I		○	○					IFF
								RF energy
								Digitized 155-mm firepower
								Increased autonomous footprint
Advanced Concept								
Guided MLRS	○	○			○	○		
Precision-Guided Mortar Munition	○	○			○	○		Autonomous or surgical kill for infantry
MOBILITY							Composite technology	
System							Autonomous operation	
Crusader	○	○		○	●	○	Land, water, air movement	
Lightweight 155-mm Towed Howitzer	●	○		○	●	○	Onboard navigation	

● Provides significant capability ○ Provides some capability

Table III–33. Fire Support Demonstration and System Summary

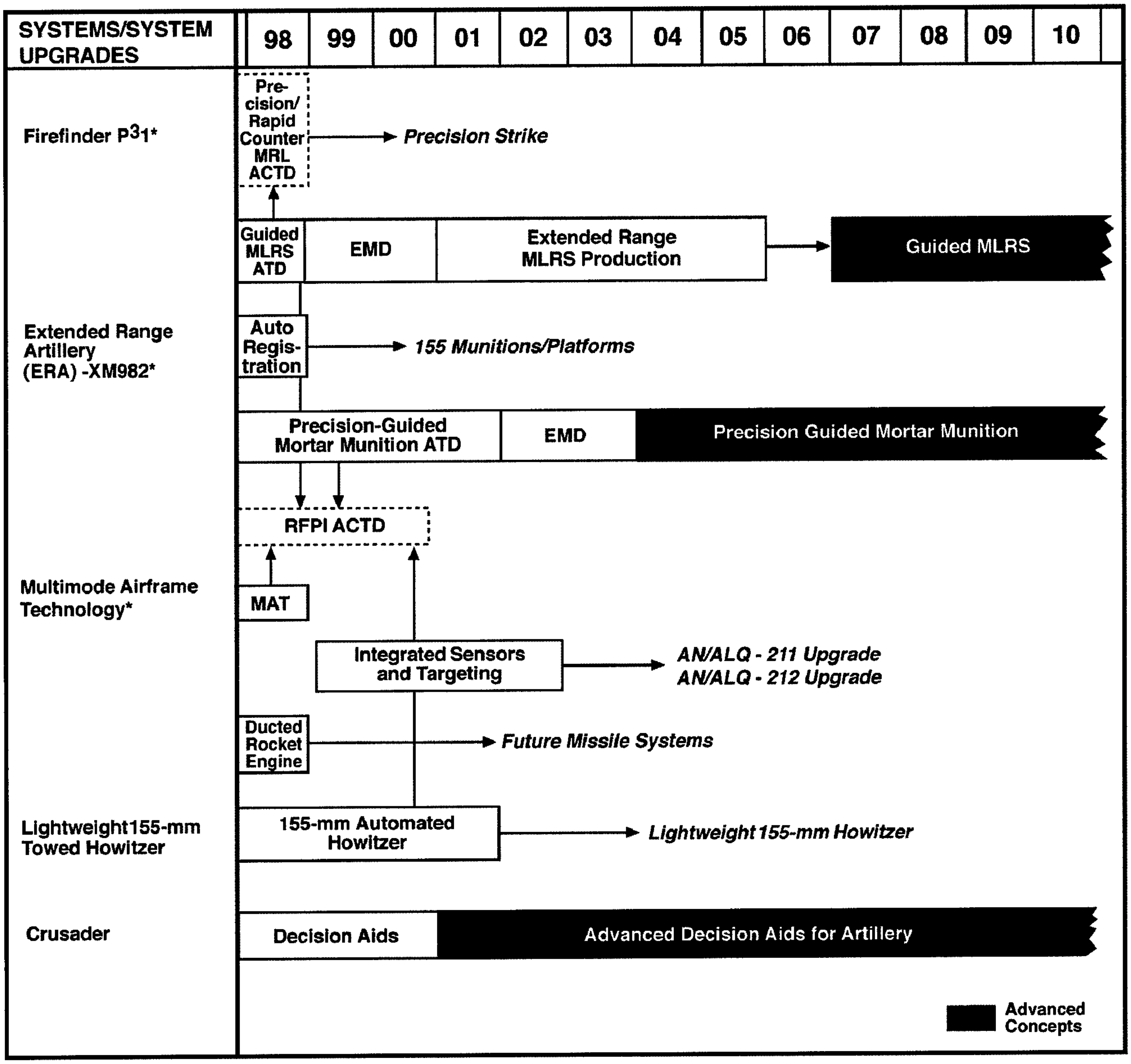
Advanced Technology Demonstration	Technology Demonstration
Precision-Guided Mortar Munition (see Close Combat Light) Guided MLRS	Decision Aids for Advanced Artillery and Decision Aids 155-mm Automated Howitzer Ducted Rocket Engine Multimode Airframe Integrated Sensors and Targeting Auto-Registration
Advanced Concept Technology Demonstration	
JPSD Precision/Rapid Counter MRL Rapid Force Projection Initiative (see Close Combat Light) (For additional information, see Volume II, Annex B.)	

System/System Upgrade/Advanced Concept	
System	**Advanced Concept**
Crusader	Precision-Guided Mortar Munition
Lightweight 155-mm Towed Howitzer	Guided MLRS
System Upgrade	Advanced Decision Aids for Artillery
Firefinder P^3I	155-mm Automated Howitzer
Multimode Airframe Technology	
Extended Range Artillery (ERA) Projectile—XM982	

a. ATDs and Other Technology Demonstrations

Guided Multiple Launch Rocket System (MLRS) ATD (1995–98). This ATD will demonstrate a significant improvement in the range and accuracy of the MLRS free-flight artillery rocket. Improved accuracy results in a significant reduction in the number of rockets required to defeat the target (as much as sixfold at extended ranges). Other benefits include an associated reduction in the logistics burden (transportation of rockets), reduced chances of collateral damage and fratricide, reduced mission times (resulting in increased system survivability), and increased effective range for the MLRS rocket. The ATD will design, fabricate, and flight test a low-cost guidance and control package to be housed in the nose of the rocket, thus minimizing the changes to the current rocket. A low-cost inertial measurement unit (IMU) coupled with a canard control system will be demonstrated in Phase I, followed by a GPS-aided IMU solution in Phase II. The IMU package will provide a 2 to 3 mil accuracy sufficient for some MLRS warheads with the GPS-aided package providing a 10-meter CEP accuracy for warheads that require precision accuracy. The package to be demonstrated will result in a rocket that is more cost effective and more lethal while requiring no change to crew training procedures or maintenance procedures (during the 15-year shelf life). The guidance and control package will be designed with applicability to bomblet, mine, precision guided submunition, and unitary/earth penetrator warheads. An EMD program is in the POM with an FY98 start. *Supports:* RFPI ACTD and Guided MLRS.

Precision Guided Mortar Munition (PGMM) ATD (1994–01). The 120-mm PGMM will demonstrate a multimission, multimode, precision munition capable of defeating high-value point targets at extended ranges (12–15 km). Its modes of operation include autonomous fire-and-forget and laser designation for a surgical strike capability. Accuracy improvement, such as GPS/inertial navigation system (INS) technologies, will be developed to further improve accuracy and effectiveness at long ranges. In FY99 demonstrations included both



*System upgrade.

Figure III–20. Roadmap—Fire Support Modernization

laser-designated and autonomous fire missions. In FY01 demonstrations included comprehensive hardware-in-loop (including GPS/INS) testing. See the section on Close Combat Light (above), for details. *Supports:* RFPI ACTD, 120-mm Mortars, and PGMM.

Auto-Registration TD (1996–98). This program will develop and demonstrate an autoregistration system utilizing a digital GPS P/Y code translator (in a NATO-standard fuze) and platform receiver to track artillery projectiles and automatically compute firing corrections. This will provide significant accuracy improvement, at all ranges, for all projectiles on all platforms. The demonstration will take place at Yuma Proving Ground and the Field Artillery School at Fort Sill, and will consist of a series of test firings that will compare predicted fire to autoregistration accuracy. *Supports:* All existing and future 155-mm munitions/platforms.

Rapid Force Projection Initiative (RFPI) ACTD (1995–00). This ACTD will demonstrate a

highly lethal, survivable, and rapidly air deployable enhancement to the Early Entry Task Force. It includes an automated fire control system for selected howitzers, the EFOGM non-line-of-sight weapon system, and the IAS as a deep/shallow emplaced sensor. Further details are provided in the section on Close Combat Light (above).

155-mm Automated Howitzer (AH) TD (1994–01). This program will demonstrate an automated, digital fire control system for a 155-mm towed artillery system. The digital FCS has self-location and direction determination. The FCS performs onboard ballistic calculations that provide the system with greater responsiveness, accuracy, lethality, and survivability. The advanced fire control technology supports the RFPI ACTD and subsequent ACTD. Automation such as self-location and direction determination are expected to increase efficiency, responsiveness, and accuracy. *Supports:* LW Howitzer 155 Program and RFPI ACTD.

Decision Aids for Advanced Artillery and Armament Decision Aids TD (1994–00). The initial demonstrations evaluate a prototype decision-aid system for self-propelled artillery, utilizing artificial intelligence and advanced computing techniques. The system consists of two decision aid modules: reconnaissance, selection, and occupation of position (RSOP) and self-defense. It will reduce planning time required for movement to a new fire position, decrease response time to a new mission, and increase self-survivability capability. The follow-on demonstration (armament decision aids) will build upon previously developed technology and link the individual fire support platform to the digitized battlefield. This demonstration will allow individual or groups of fire support platforms to operate, as needed, outside of the traditional fire support C^2 structure and fully exploit new plans, procedures, and tactics of the digital battlefield. Benefits will include improved situational awareness, synchronized movement with maneuver forces, and, ideally, fratricide avoidance. *Supports:* Crusader.

JPSD Precision/Rapid Counter MRL ACTD (1995–98). This ACTD will demonstrate a significantly enhanced capability for U.S. Forces Korea to neutralize the North Korean 240-mm MRL system. Because of the brief time in which this target is expected to be exposed and vulnerable to counterfire, near-continuous surveillance and near-instantaneous target acquisition will be required, as well as the employment of innovative target attack means. Smart munitions for the MLRS family of submunitions (MFOM) will be demonstrated through simulations in the ACTD to include smart munitions for increased effectiveness and coverage. Project management and funding will continue through FY98. *Supports:* Precision Strike.

Ducted Rocket Engine (DRE) TD (1996–98). The DRE program is a joint R&D effort with Japan to develop and demonstrate a ducted rocket engine for a medium surface-to-air missile that will significantly increase the intercept envelope against aircraft and cruise missiles when compared with surface-to-air missiles utilizing current solid rocket propulsion technology. It is the first developmental program under the auspices of the U.S. Department of Defense/Japan Defense Agency Systems and Technology Forum (S&TF). The component technology development and engine demonstration effort is focused on the design and testing of a minimum signature, insensitive munitions-compatible booster, having supersonic air inlets, and a solid fuel gas generator providing high-impulse, minimum signature ramburner operation. Performance data acquired from the DRE program integrated tests may provide a basis for the design of a future, operationally deployable surface-to-air or long-range surface-to-surface missile system. *Supports:* Future missile systems, Battle Command, Depth and Simultaneous Attack, Early Entry Lethality, and Survivability Battle Labs.

Multimode Airframe Technology (MAT) TD (1995–98). This TD will provide the battlefield commander with a long-range (40+ km) precision-guided artillery weapon that will provide light forces with surgical kill capacity against

heavy armor, helicopter, and bunker targets. Further, it will provide extended-range and precision terminal homing capabilities, enhanced survivability and lethality, jam-proof datalink, and low-signature turbojet launch using GPS/IMU for navigation. *Supports:* RFPI ACTD and JPSD Precision/Rapid Counter MRL ACTD.

Integrated Sensors and Targeting TD (1999–02). This program will develop a leap-ahead targeting upgrade to the suite of integrated RF countermeasures (AN/ALQ–211) and suite of integrated IR countermeasures (AN/ALQ–212). Apache Longbow AH–1D aircraft will have precision geolocation and targeting of emitters on the battlefield. Using its integral variable message format (VMF) interface to onboard communications systems, Apache Longbow will be capable of providing command posts, fire support units, and ground vehicles with real-time coordinates with friend or foe classification of radar emitters on the battlefield. *Supports:* PM–Airborne Electronic Combat's (AEC) EMD Technology Upgrades to the AN/ALQ–211 and ALQ–212.

Advanced Sense and Destroy Armor (SADARM) Sensor TD (1998–01). This program will demonstrate the application of a common aperature LADAR/IR transducer to enhance the current smart submunition (SADARM) sensor suite for use in gun launch environments. The enhanced sensor suite performance will greatly reduce cost per kill for the basic SADARM. *Support:* SADARM improvements.

Future Direct Support Weapon TD (1998–01). This program is to demonstrate the viability of a 5000–lb 155mm towed howitzer. The program consists of two major phases with the first phase to demonstrate a 6750–lb towed howitzer, then a 5700–lb howitzer in second phase. This program will leverage technologies such as electro-rheological fluid and recoil management, advanced materials and structures to reduce system weight. *Support:* 155mm towed howitzer for light forces.

5. Relationship to Modernization Plan Annexes

Table III–34 shows the correlation between the Fire Support S/SU/ACs and other AMP annexes.

Table III–34. Correlation Between Fire Support S/SU/ACs and Other AMP Annexes

System/System Upgrade/Advanced Concept		Modernization Plan Annexes: Close Combat Light*	Mounted Forces*	IEW	Space & Missile Defense
System	Crusader	○	●		
	Lightweight 155-mm Towed Howitzer	●	○		
System Upgrade	Firefinder P^3I	○	○	●	
	Multimode Airframe Technology	●			●
	Extended-Range Artillery Projectile—XM982	●	●		
Advanced Concept	Precision-Guided Mortar Munition	●	○		
	Guided MLRS	●			
Advanced Concept	Advanced Decision Aids for Artillery		●		

* See Combat Maneuver Annex.
● System plays a significant role in the modernization strategy
○ System makes a contribution to the modernization strategy

O. LOGISTICS

There will not be a revolution in military affairs until there is a revolution in logistics.

General Dennis J. Reimer
Army Chief of Staff

1. Introduction

Logisticians provide the means with which the warfighters can execute their war plans, strategy, and tactics. The *Joint Vision 2010* requires that our forces maintain a dominant maneuver capability. For the land component, dominant maneuver consists of two elements: strategic and operational. Strategic maneuver equates to the Army's requirement to project the force. This power projection force will be lighter and more durable, with multipurpose warfighting systems that will reduce the amount of lift required as well as the size and complexity of the logistics needed to sustain the force.

Reduce the logistics footprint on the battlefield ... reduce logistics OPTEMPO by 30% and the logistics O&S costs by 25% ....

General Dennis J. Reimer
Army Chief of Staff

The DoD S&T community has identified six Strategic Research Objectives (SROs) that are the highest priority in terms of developing advanced technologies to meet requirements. These are smart structures, biomimetics, nanoscience, broadband communications, intelligent systems, and compact power sources. The Army's new SRO, Research for Innovative Logistics, complements these DoD SROs. The logistics S&T community fully supports the focused logistics capability as defined in *Joint Vision 2010, Army Vision 2010,* through its Revolution in Military Logistics Campaign Plan—The Way Ahead (commonly referred to as the RML). The RML provides categories of "enablers," one of which is advanced technologies. These advanced technology enablers complement the six critical technologies from the DoD SROs.

The AAN mission is to conduct broad studies of warfare to about the year 2025 to frame issues vital to the Army after about 2010, and to provide issues to the senior Army leadership for integration into TRADOC combat development programs. One goal of The AAN is to link technological possibilities to innovative operational capabilities. To this end, the AAN Logistics Efficiencies Panel has further broken out the requirements for advanced technology applications in the areas of power, distribution, soldier sustainment, system sustainment, ammunition, and C^4I.

Think out of the box! Find the Ah-ha's!

Major General Robert Scales
Deputy Chief of Staff for Doctrine

The technology initiatives that the logisticians are pursuing directly support the goals of *Joint Vision 2010, Army Vision 2010,* the chief of staff's guidance, and other pertinent documents. For example, on board prognostics will not only eliminate the requirement to deploy vast quantities of dissimilar test equipment but also provide real-time predictions of impending failure. This ability to predict future failure will reduce collateral damage due to failed parts and reduce the time for repair for the warfighter; prognostics will alert a combat commander to impending failure of combat vehicles prior to entering into a decisive engagement with enemy forces.

2. Relationship to Operational Capabilities

Logistics system upgrades and advanced concepts and their link to the Army modernization objectives are shown in Table III–35. This table also displays the operational capabilities provided by each of the SU/ACs.

3. Logistics Modernization Strategy

The Logistics annex of the AMP focuses on the objective of "project and sustain the force."

Table III–35. Logistics System Capabilities

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
PROJECT							Improved precision-guided delivery of munitions Reduced weight and bulk of cargo and personnel parachutes Lower ground impact velocities for cargo airdrop systems Lower impact forces for cargo airdrop systems	Accurate delivery of supplies/equipment from offset distances Increased delivery accuracy via an autonomous GPS-based guidance and navigation system Covert day/night and limited visibility airdrop capability
System Upgrade								
Aerial Delivery								
Advanced Cargo Airdrop Technologies	●	○		●	○	●		
Advanced Concept								
Precision Offset, High Glide Aerial Delivery	●	○		●	○	●		
SUSTAIN							Shelf stable ration components Enhanced rations performance and flexibility Reduce rations weight and volume Less soldier labor/fatigue Reduced manpower Automated assessment of petroleum products Improved corrosion protection Improved munitions protection Improved morale/quality of life Improved food, nutrition, readiness Lower O&S cost Versatile new fuel/energy source Improved quality of life (food, water) Improved air transportability	
System Upgrade								
Army Field Feeding Future	●	○				●		
Advanced Lightweight Portable Power/Silent Energy Source	●					●		
Rapid Deployment Food Service for Force Projection	●	○				●		
Mobility Enhancing Ration Components	●	○				●		
Emerging Petroleum Quality	●			○	○	○		
Reforming Diesel to Refuel Soldiers	●					●		
Munitions Survivability	○	○		○		○		

Table III–35. Logistics System Capabilities (continued)

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation						System/ System Upgrade Capability	Advanced Concept Capability
	Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force		
Embedded ammo info device	○		○			●	Survivable munitions storage area:	
Future combat system logistics	●	○				●	• Improved ammunition readiness • Inventory/expenditure rate data for anticipatory logistics • Reduced rearm times • Improved rates of fire • Less soldier labor/fatigue • Reduced manpower • Saves lives/combat power • Improved munitions accuracy • Improved prognostics/diagnostics	Increased mobility, deployability, reliability, and maintainability
Advanced Concept								
Containerized Kitchen	●	○				●		Increased mobility, deployability, reliability, and maintainability

● Provides significant capability ○ Provides some capability

To project and sustain the force in support of Force XXI and the AAN, as presented in RML, the Army will need to find technology solutions to overcome the realities of prior and projected force reductions. Many of these technologies are currently under development through ATDs and TDs from other mission areas. In order to portray the complete picture of Army Logistics, as influenced by these other initiatives, Table III–36 is presented. This table shows the direct and significant impact upon the efficiencies, operational concepts, and costs of logistics functions provided by these intitiatives. It details the initiative, the mission area, the vision supported and the benefits to Army Logistics. Their impact upon the Logistics community's capability to project and sustain the current and future force cannot be understated.

To *project the force* the logistics community needs:

- Key information technologies that rapidly and automatically identify and track assets.
- Access to and use of theater entry technologies such as battlefield visualization and situational awareness.
- Advanced thermodynamic material for unattended, tamper-proof, climatically controlled "smart" containers.
- Access to and use of theater command and control technologies.

Table III–36. Modernization Payoffs of Technologies for Logistics

Initiative	Vision Supported: *Joint Vision 2010*	*Army Vision 2010*	RML	*Army After Next*	DoD Strategic Research Objectives	Benefit of Initiative
Project the Force						
Perform Enhancing Demonstrations	●	●	●			Enables personnel to perform at high levels of performance for extended time
Rapid Deployment Food Services	●	●	●			Provides a 50% increase in MTBF with a 50% decrease in fuel usage
Reforming Diesel to Refuel Soldiers	●	●	●		●	Provide a technology to reform diesel fuel into a versatile fuel that can be cleanly and reliably burned
Sustain the Force						
Rotorcraft Pilot's Associate		●	●			Provides high-speed data fusion processing and cognitive decision–aiding expert systems
Battlespace Command and Control	●	●	●	●	●	Provides EEI required for velocity management and battlefield distribution
Digital Battlefield Communications	●		●	●	●	Provides "bandwidth on demand" to support multimedia information requirements
Vehicle Mounted Mine Detector			●			Provides mounted capability to detect metallic and nonmetallic mines—resupply
Battlefield Combat Identification	●		●	●	●	Provides situational awareness to prevent fratricide—resupply, maintenance missions
Future Scout and Cavalry System			●			Provides advanced lightweight materials and electric drive to be supplied and maintained
Rapid Terrain Visualization	●		●	●	●	Provides battlefield situational awareness required to plan and execute log missions
Joint Logistics	●		●			Provides rapid integration log data to meet Army and joint mission requirements
Precision Offset Aerial Delivery	●		●		●	Provides reliable precision-guided delivery of combat essential munitions and equipment
Helicopter Active Control Technology			●			Enables advanced fault-tolerant systems to maintain reliability and simplify maintenance
Aircraft System Self-Healing	●		●	●	●	Compensates for premature subsystem or component failure, changes repair concept
Munitions Survivability	○	○	○			Provides advanced materials, barricades, and blankets for munitions survivability
Embedded Ammo Information Device	○	○	○	○		Enables anticipatory resupply and prognostics/diagnostics, improves readiness, improves munitions accuracy
Future Combat System Logistics	○	○	○	○		Provides rapid integrated seamless rearm and resupply for FCS
Mobility Enhanced Ration Components	●		●			Provides shelf-stable, no-preparation rations compatible with existing ration systems
Munitions Survivability	●	●	●			Ensures the survivability of munitions at ports, airheads, and munitions storage areas

Table III–36. Modernization Payoffs of Technologies for Logistics (continued)

Initiative	Vision Supported: Joint Vision 2010	Army Vision 2010	RML	Army After Next	DoD Strategic Research Objectives	Benefit of Initiative
Survivable, Affordable, Repairable Airframe Program	•		•	•	•	New efficient and affordable diagnostics and repair concepts—30% reduced repair times
Fourth-Generation Crew Station	•		•	•	•	Provides advanced 3D display technology transferable to telemaintenance
Integration High-Performance Turbine Engine	•		•	•	•	25% reduction in fuel consumption and a 60% increase in power-to-weight ratio
Alternate Propulsion Sources	•		•	•	•	Explores advanced propulsion concepts beyond air-breathing propulsion
Electrical Power Generation	•		•	•	•	Provides light, highly mobile power sources capable of operating on multiple fuels
On-Board Integrated Diagnostic System (OBIDS)	•		•	•	•	Reduces maintenance 15%, O&S 10%, maintenance cost/flight hour 50%; increases reliability 45%
Ground Propulsion and Mobility	•		•			Provides critical engine, electronic drive, track and suspension, and storage devices
Advanced Electronics Future Combat System	•		•	•	•	Advanced concepts to resupply power and distribution systems will need to be developed
Future Combat System Integrated Demonstration	•		•	•	•	Provide high-power electric technology critical to leap-ahead capabilities within combat vehicle
Future Combat System Mobility	•		•			Provides an electric drive and power conditioning system; an active suspension system
Universal Transaction Comm	•		•	•	•	Information to flow—wherever it exists, in any form, to wherever it is needed in any form
Third-Generation Advanced Rotor Demonstration	•	•	•		•	Increases range 36% or payload 98%, reliability 45%; reduces O&S costs 10%
Advanced Rotorcraft Transmission II		•	•		•	Provides 25% weight reduction, increases MTBR; significantly reduces O&S costs
Structural Crash Dynamics (M&S)		•	•		•	Provides design and performance evaluation tool to be optimized for helicopter systems
Rotor-Wing Structures Technology		•	•		•	Increases reliability 20%, maintainability 10%; reduces O&S 5% for utility type rotorcraft
Advanced Rotorcraft Aerodynamics		•	•		•	Reduces MTBF; increases reliability and maintainability; and reduces O&S costs
Subsystem Technology Affordability and Supportability		•	•		•	Overcomes technical barriers associated with advanced digitized maintenance and real-time OBIDS
Subsystem Technology for IR Reduction		•	•		•	Repair and maintenance of advanced multispectral coatings require specialized maintenance training
Intravehicle Electronics Suite	•	•	•	•	•	Validates real-time performance requirements for VEtronics open systems architecture
Military Operations in Urban Terrain	•	•	•			Open system architecture facilitates a large reduction in future ILS life-cycle costs

Table III–36. Modernization Payoffs of Technologies for Logistics (continued)

Initiative	Vision Supported: *Joint Vision 2010*	*Army Vision 2010*	RML	*Army After Next*	DoD Strategic Research Objectives	Benefit of Initiative
Joint Speakeasy	●	●	●		●	Flexible radio architecture, rapid waveform reprogrammability/reconfigurability
Range Extension	●	●	●		●	Technical supplement current (and programmed) SATCOM resources, all frequency bands
Machine Visualization-Autonomous Unmanned Ground Vehicle	●	●	●		●	Provides capability to ensure resupply continues at the required level and timeliness
SATCOM Technology	●	●	●	●	●	Provides higher data rates, improvements in throughput, and reduced life-cycle costs
Advanced Cargo Air Drop Technology	●	●	●		●	Provide improved performance characteristics and enhanced safety of existing personal parachute capabilities

● Provides significant capability

To *sustain the force* the logistics community needs smart combat systems that have:

- Ultra-reliability built into them during manufacture.
- Built-in self-prognostics that report future failures automatically.
- Self-healing subsystems that provide the capability to delay repairs and continue to prosecute the battle.
- Alternative propulsion systems and fuels.
- "Smart" materials that self-heal and change to the demands of the battlefield.
- Biomimetic materials that provide quantum increases in strength and are noncorrosive and nonerosive.
- Sensors and AI that will enable resupply and repair movements about the battlefield with a high degree of impunity.
- Battlefield situational awareness.
- Nanotechnology applied to battlefield manufacture of supplies as well as the maintenance and repair of combat equipment.

4. Roadmap for Army Logistics

Table III–37 presents a summary of TDs, ACTDs and SU/ACs in the Logistics S&T program that support Logistics modernization. The roadmap at Figure III–21 portrays the projection and evolution of these programs in support of Logistics modernization.

a. RML Domain: Force Projection

Precision Offset, High-Glide Aerial Delivery TD (1994–99). Semirigid deployable wing (SDW) technology will be used to demonstrate precision, high-offset delivery of supplies and equipment. Details can be found in the section on Close Combat Light (above). *Supports:* Aerial Delivery, Precision Offset, High-Glide Aerial Delivery, EELS, DSA, and CSS Battle Labs.

Advanced Cargo Airdrop Technologies TD (1998–00). This TD will demonstrate technologies to provide an improved cargo airdrop capability. Utilizing novel design techniques, demonstrate a personnel size parachute (interim goal) by the

Table III–37. Logistics Demonstration and System Summary

Advanced Concept Technology Demonstration	Technology Demonstration
Joint Logistics	**Project Demonstrations**
	Precision Offset, High-Glide Aerial Delivery
	Advanced Cargo Airdrop
	Sustain Demonstrations
	Rapid Deployment Food Service for Force Projection
	Mobility-Enhancing Ration Components
	Field Feeding/Logistics Fuel
	Electric Power Generation
	Munitions Survivability
	Embedded Ammo Information Device
	Future Combat System Logistics
	Reforming Diesel to Refuel Soldiers
	Emerging Petroleum Quality

System/System Upgrade/Advanced Concept	
System Upgrade	Combat System Logistics
Advanced Cargo Airdrop	Future Combat System Logistics
Aerial Delivery	Reforming Diesel to Refuel Soldiers
Army Field Feeding Future	Munitions Survivability
Rapid Deployment Food Service for Force Projection	Mobility-Enhancing Ration Components
Advanced Lightweight Portable Power Generation/ Silent Energy Source	Emerging Petroleum Quality
Munitions Survivability	**Advanced Concept**
Embedded Ammo Information Device	Precision Offset, High-Glide Aerial Delivery
	Containerized Kitchen

end of FY97 and, by the end of FY00, a cargo-size parachute with a 20 percent reduction in weight, bulk and manufacturing costs (compared to fielded parachutes) while providing equivalent flight performance. By the end of FY98, demonstrate a parachute retraction system using clustered parachutes that provide a less than 10 feet/second soft landing capability. This capability will allow for airdrop of critical items (such as robotics) too fragile for airdrop with conventional systems. By the end of FY00, demonstrate a less than 10 g soft landing airbag system that will provide an all-weather, rapid roll-on/roll-off airdrop capability for the future Army. *Supports:* FOCs QM 97–001: Aerial Delivery; IN 97–301: Mobility—Tactical Infantry Deployability; AD 97–001: Deployability.

b. RML Domain: Force Sustainment

Joint Logistics ACTD (1998–99). The Joint Logistics ACTD will develop and demonstrate an automated joint logistics awareness and analysis capability to view the logistics battlespace, collaborate in shared information, and integrate existing strategic and operational logistics data and tools. This will be achieved through a network of workstations connecting operational planners and logisticians across services and echelons, and by using advanced data distribution and visualization techniques. The network provides the platform for the rapid integration of logistics data and tools adaptable to meet Army and joint mission requirements in CINC exercises and operational contingencies. This ACTD, which is Global Command and Control System (GCCS) compliant, will also integrate existing logistics models with knowledge-based tools to provided decision support to the commanders. *Supports:* Force XXI, Vision 2010, and RML.

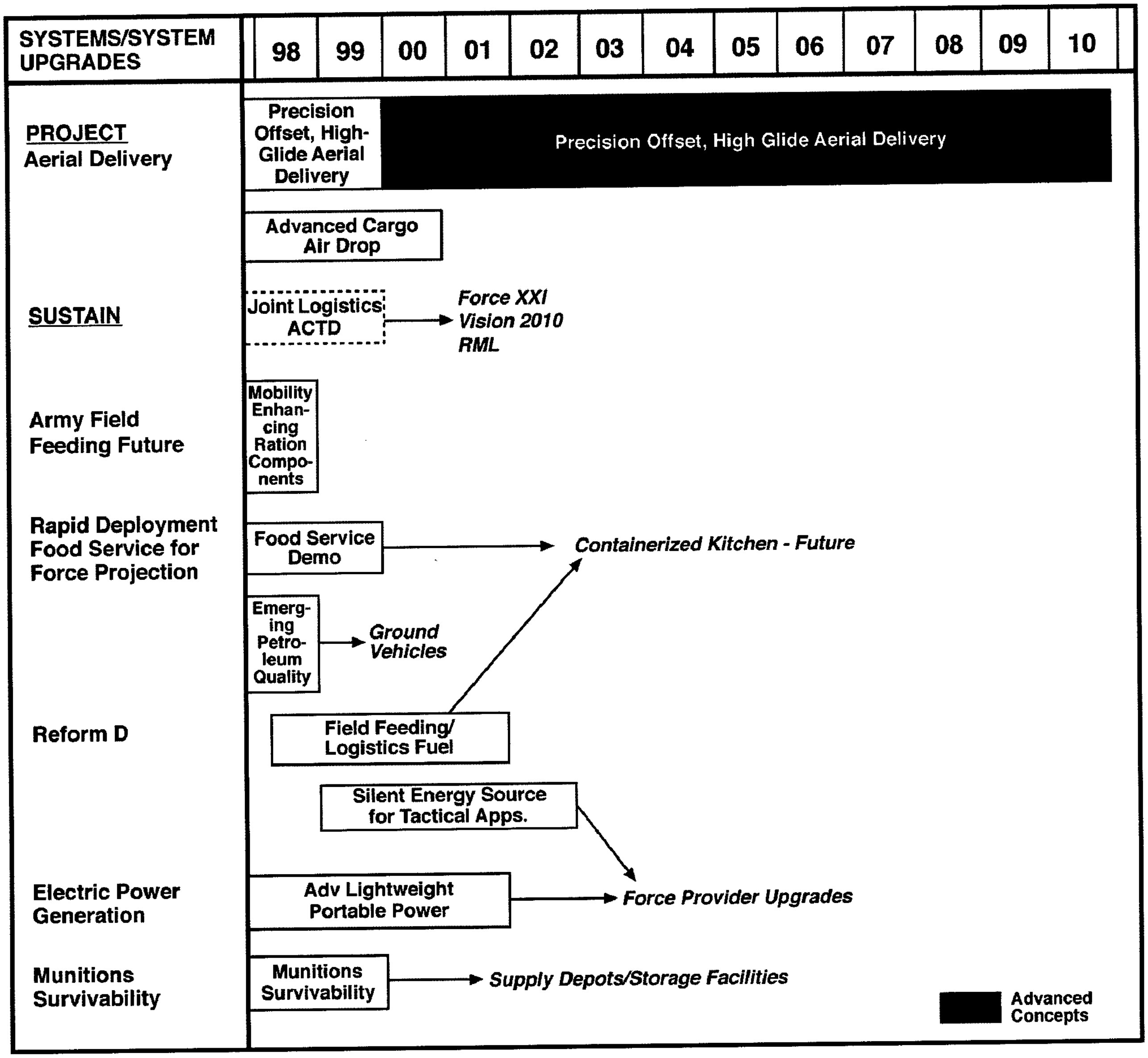


Figure III–21. Roadmap—Logistics Modernization

Rapid Deployment Food Service for Force Projection TD (1994–99). With renewed emphasis on fresh foods and changes in Army policy from two hot meals per week to one a day, fundamental changes are required in field kitchens to support rapid force projection. This program will demonstrate advances in diesel combustion, heat transfer, power generation, and food storage. The fundamental changes in kitchen design will include centrally heated equipment, integral power, and heat-driven refrigeration. These technologies will be developed, integrated with other improvements on a kitchen platform and demonstrated in field scenarios. The demonstrations will show necessary increases in mobility, deployability, reliability, maintainability, and efficiency that will yield higher quality meals faster and cheaper. *Supports:* Rapid Deployment Food Service for Force Projection.

Mobility Enhancing Ration Components (MERCs) TD (1996–98). By FY98, MERCs will demonstrate technologies of shelf-stable, highly acceptable, eat-on-the-move/eat-out-of-hand

components for operational rations. Ration components will be suitable for individual or group ration systems that support highly mobile and deployed troops. MERCs will be suitable for arctic, jungle, desert, mountain, and urban environments. The goal is to provide novel ration components (e.g., shelf-stable sandwiches) that can be consumed on-the-go with no preparation or heating required and that are compatible with existing ration systems. *Supports:* Army Field Feeding Future.

Advanced Lightweight Portable Power TD (1998–01). This TD will support the Army's vision of the digitized battlefield by developing light, highly mobile, signature-suppressed power sources capable of operating on multiple fuels in all hostile environments. Designs will be based on evaluation and integration of commercially available engines and state-of-the-art alternator and power electronic technologies. The goal is to enhance electrical generation, storage, and conditioning capabilities required to support Tactical Operations Center (TOCs), communication/weapon systems and sensors of the 21st century battlefield. *Supports:* Electric Power Generation, Force Provider Upgrades, and RML.

Silent Energy Source for Tactical Applications (1999–02). This program will demonstrate silent lightweight, liquid-fueled fuel cell power sources in the 50–150 watt range for various soldier applications. These power sources are aimed at offering lighter more energetic power sources than are currently available and would extend mission time, reduce weight, and decrease the logistics burden associated with current power sources. *Supports:* Electric Power Generation, Force Provider Upgrades, and RML.

Emerging Petroleum Quality TD (1994–98). Advanced technology and automated devices/systems will be employed to provide rapid on-the-spot assessment of bulk and packaged petroleum products from CONUS or host nation support. The advanced technologies being demonstrated for petroleum quality analysis (PQA) will use automated analytical techniques and emerging methodologies in conjunction with computer-based expert systems. The devices/systems will replace all existing petroleum laboratories, reduce testing time from 3 hours to 10 minutes, and decrease manpower requirements by 75 percent. This emerging technology is state-of-the-art and will serve as a foundation for follow-on industry efforts. PQA will provide commanders the combat service support equipment required to enhance sustaining momentum, maintaining operational/tactical maneuver freedom, and optimizing the use of locally available supplies. The capability to utilize locally available petroleum products with attendant risks will significantly reduce logistics and enhance mobility of forward units. *Supports:* Logistics Survivability and all ground combat vehicles.

Reforming Diesel to Refuel Soldiers TD (1998–01). Reforming diesel fuel (and JP–8) into a versatile gaseous fuel will allow modern, efficient gas appliances to replace gasoline and diesel fueled equipment in field kitchens. This will reduce field feeding costs while allowing for significant improvements in the kitchen as a work environment and the cook's ability to prepare high-quality meals. An added benefit is the ability to dispense safely the reformed fuel into bottled cartridges to power soldier individual equipment. This program will include technology and technical demonstration of a field kitchen with commercial gas cooking appliances powered by a diesel-to-gas reformer. Additionally, a soldier refueling concept will be demonstrated whereby the field kitchen is a logistic supply point that fuels individual soldiers and their equipment. *Supports:* Army Field Feeding Equipment 2000.

Munitions Survivability TD (1997–99). This TD will develop advanced explosive propagation technologies to ensure the survivability of munitions at ports, airheads, and munitions storage areas. High-performance fire-blocking/-retarding materials and blast absorbing designs will be developed to prevent fire and explosive propagation between munitions stacks. This technology will limit ammo loss to only 1 percent

from a ballistic missile direct hit and will reduce ammo storage area footprint by 60 percent. The program provides a low-cost approach to protect decisive munitions and is critical component of force protection and force projection. *Supports:* Munitions Survivability; CSS, DSA, and EELS Battle Labs, and RML.

Embedded Ammunition Information Device TD (FY00–02). This program will demonstrate extremely small, low cost microchip-based devices that can be embedded in munitions and related packaging to provide: remote wireless tracking of expenditure rates and logistics data in support of anticipatory resupply, monitoring of environmental data (shock, temperature, barometric pressure, humidity, etc.) for remote quality assurance inspections, enable prognostics/ diagnostics, and "reading of temperature data by fire control systems to improve munitions accuracy." The devices will incorporate single-chip miniature radio frequency (RF) tranceivers, micro-machined environmental sensors, and memory that can be read and written to with RF energy. A device that functions solely from the RF energy from an associated "reader" as well as a battery-powered device will be demonstrated. The battery-powered device will be able to accommodate a full environmental sensor suite and transmit information over greater distances than the battery-free device. The result will be significantly improved logistics efficiency through anticipatory resupply, improved readiness via enhanced quality assurance of the stockpile, and improved munitions accuracy resulting from knowledge of certain environmental parameters that affect ballistics.

Future Combat System Logistics TD (FY00–04). This program will develop technologies to reduce the logistics burden and increase battlefield survivability for the Future Combat system (FCS). After this period, efficient focused resupply of ammunition is required. This program will demonstrate high efficiency modular packaging, a rapid theater distribution system that provides ammunition directly to the FCS in the field, and an automated upload system that loads ammunition into the FCS autoloader , to reduce rearm times by up to 50% over the status quo, manual, labor–intensive logistics system. The result will be an integrated, seamless system that increases the FCS firepower by decreasing rearm downtime and helps the FCS achieve its system requirement to reduce the logistics burden by 50%.

5. Relationship to Modernization Plan Annexes

Table III–38 shows the correlation between the Logistics SU / ACs and other *Army Modernization Plan* annexes.

6. Logistics Annex of the ASTMP

The Logistics Annex of the ASTMP provides for a comprehensive presentation of what is being developed to fulfill the RML requirements to project and sustain the force.

Table III–38. Correlation Between Logistics S/SU/ACs and Other AMP Annexes

	System/System Upgrade/Advanced Concept	Close Combat Light*	Soldier Systems	Aviation	C^4	Combat Health Support	Fire Support	Mounted Forces	Space & Missile Defense	Tactical Wheeled Vehicles*
System Upgrade	Aerial Delivery	●	○	●						
	Army Field Feeding Future	○	●			○				
	Rapid Deployment Food Service for Force Projection	○	●							
	Reforming Diesel to Refuel Soldiers	○	●			○				
	Advanced Lightweight Portable Power/Silent Engine Source				○	○			○	
	Munitions Survivability	●		●			●	●	●	
	Advanced Cargo Airdrop	●								
	Embedded Ammo Information Device	●		●			●	●	●	
	Future Combat System Logistics							●		
	Emerging Petroleum Quality	○		○				○		
	Mobility Enhancing Rations	○	●							
Advanced Concept	Precision Offset, High-Glide Aerial Delivery	○	○	●						
	Containerized Kitchen	○	●			○				

(Column group header: Modernization Plan Annexes)

* See Combat Maneuver Annex.
● System plays a significant role in the modernization strategy
○ System makes a contribution to the modernization strategy

P. TRAINING

We must find the best ways to organize, train, and equip our forces to exploit our competitive advantages—quality people and advanced technology.

General Dennis J. Reimer
Army Chief of Staff

1. Introduction

The new national security strategy stresses preparation to defend against nuclear threats, threats from regional powers, threats to evolving democratization, and regional instabilities. A force projection Army must be ready to carry out changing roles and missions at any time, anywhere in the world.

Army training can meet this challenge through the application of behavioral science and emerging technologies to individual/land warfare training, simulation-enhanced training, battle command training, and unit training. These advances will be used to increase mission readiness for both active and reserve forces and improve the training for new missions. Commanders will be able to provide tough, realistic, battle-focused training to provide soldiers and leaders with the ability to fight and win within a constrained training budget.

2. Relationship to Operational Capabilities

The combined arms training strategy (CATS) is the Army's architecture for training and educating its people and units. CATS provides the conceptual framework for establishing training policy and resource requirements. The objective of the CATS architecture is to provide doctrine-based strategies for training warfighting tasks and skills in institutions, units, and through self-development.

Table III–39 presents the correlation between TRADOC's battlefield dynamics and training SU/ACs. It also shows proposed training system capabilities by battlefield dynamics. Simulation-based training and training strategies cut across all battlefield dynamics, although special emphasis is given to combined arms operations for both large and small units.

3. Army Modernization Strategy

America's 21st century Army will train on a digitized battlefield consisting of a close integration of live, virtual, and constructive simulations. Training strategies, organizational redesign, battle command training, and personnel issues will evolve into an interactive cycle of experimentation and assessment with actual units and in support of the battle labs.

As stated in the FY96 *Army Modernization Plan*:

> *The challenge is to train and sustain the most combat ready and deployable force in the world. The Army must look to research and development initiatives to identify technology that may offset decreasing force structure and ensure the means of providing realistic, dynamic training to our soldiers—today and tomorrow.*

Current and development system concepts are focused through the following training programs:

- Distributed interactive systems (DIS).
- Combined arms tactical trainer (CATT).
- Family of simulations (FAMSIM), including warfighters' simulation (WARSIM) 2000, tactical simulations (TACSIM), and command and control simulations.
- Combat training centers (CTCs): National Training Center (NTC), Joint Readiness Training Center (JRTC), Combat Maneuver Training Center (CMTC), and Battle Command Training Program (BCTP).
- Nonsystem training devices (NSTD).
- Range instrumentation, targetry, and devices.

Taken together, upgrades to these programs provide training aids, devices, simulators, and simulations (TADSS) that will provide the means for meeting the Army's training modernization objectives.

Table III–39. Training System Capabilities

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
VIRTUAL SIMULATION							Combined arms training Battle command training Synthetic battlefield	
System Upgrade								
Combined Arms Tactical Trainer	●	○	●	●	●	●		
Family of Simulations	●	●	●	●	●	●		
Distributed Interactive Simulation	●	●	●	●	●	●		
Combined Arms Training Strategy	○	●	●	●	●	●		
Advanced Concept								Joint mission training Mission rehearsal Mission readiness estimation Behaviorally accurate semi-automated forces (SAFOR)
Innovative Simulation-Based Training Strategies	●	●	●	●	●	●		
Assessment Technologies	●	●	●	●	●	●		
CONSTRUCTIVE SIMULATION								Joint mission training Mission rehearsal Mission readiness estimation
Advanced Concept								
Distributed Models/ Simulations for Joint/ Theater Exercises	●	●	●	●	●	●		
LIVE SIMULATION								
System Upgrade								
Combat Training Centers: NTC, JRTC, CMTC, BCTP	●	●	●	●	●	●	Performance data collection/analysis (unit performance assessment system) Contingency mission training Special operations training Joint services training Range modernization	
Nonsystem Training Devices (NSTD)	●	●	●	●	●	●	Upgrades of MILES equipment	
Range Instrumentation/ Targetry/Devices		○	●	●	●		Range modernization	

● Provides significant capability ○ Provides some capability

Future training technology initiatives must have high potential payoff (i.e., reduced training time and resource consumption). Initiatives must offer solutions that offset a decreasing force structure and ensure the means for providing realistic, dynamic training at both home station and the CTCs. CTCs must be upgraded and augmented by training aids and devices to provide a cost-effective training environment, using warfighting equipment in conjunction with simulated environments. A DIS capability combined with virtual reality (VR) technology will permit the development of synthetic battlefields for training that complement field training exercises at the CTCs.

4. Roadmap for Army Training

Table III–40 summarizes the training SU/ACs and relevant technology demonstrations. The roadmap at Figure III–22 details the Army's current plans to support future training initiatives. Limited advanced development funding for training system upgrades is available in the outyears.

CTCs represent realistic training environments using equipment on a large, instrumented maneuver area or advanced simulation programs. Standardized instrumentation systems at all CTCs provide precise measurement of unit performance in the simulated combat environments. NSTD upgrades include improved multiple integrated laser engagement system (MILES) air/ground engagement simulation (AGES II) for more effective integration of aviation operations into CTC exercises.

The CATS is the framework that will be used to design and execute effective unit training programs in a resource-constrained environment. Supporting technology demonstrations that will lead to the advanced concepts, shown in Figure III–22, are described below.

a. Unit Collective Training

The purpose of this research is to develop technologies for improving the training of units to prepare for operations envisioned for Force XXI and *Army After Next*. Technologies will include methods of improving skill retention and training transfer as we move from conventional to digital systems; multisite, multiservice, and

Table III–40. Training Demonstration and System Summary

Advanced Technology Demonstration	Technology Demonstration
Simulation in Training for Advanced Readiness	**Collective Training**
	Unit/Joint Training Readiness
	Training for the Digitized Battlefield
	Simulator-Enhanced Training
	Combined Arms Training Strategy for Aviation
	Battle Command Training
	Battle Command Skills Training

System/System Upgrade/Advanced Concept

System Upgrade	Advanced Concept
Distributed Interactive Simulation	Distributed Models/Simulation for Joint/Theater Exercises
Combined Arms Training Strategy	Innovative Simulation-Based Training Strategies
Combined Arms Tactical Trainer	Advanced Assessment and Leader Development Technologies
Family of Simulations	
Combat Training Centers	
Non-System Training Devices	
Range Instrumentation, Targetry, and Devices	

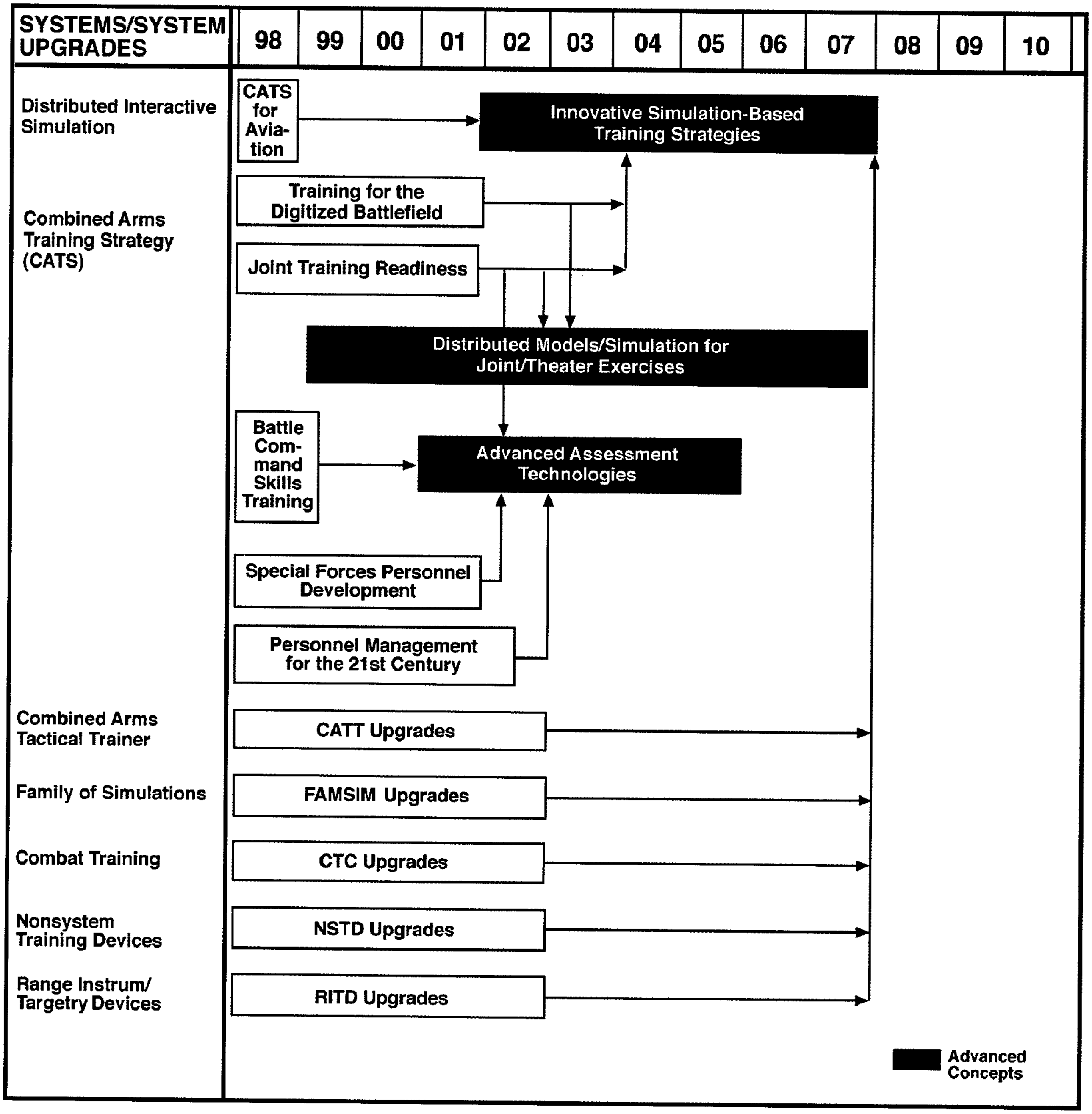


Figure III–22. Roadmap—Training Modernization

multiechelon training and assessment techniques, and techniques for evaluating the effectiveness of devices and simulators that can be used for collective training.

In FY98 this research is expected to produce structured training procedures for the new digital, close-combat tactical trainer, along with guidelines for applying these procedures to areas other than armor; improved retention of digital procedural skills for the M1A2 tank; improved methods for conducting multisite, multiservice after-action reviews (AARs), and methods of introducing cognitive modeling and situational awareness behaviors into computer-generated forces used in DIS scenarios.

b. Simulation-Enhanced Training

Today's Army must be capable of producing swift, decisive, low-casualty victories across the spectrum of conflict anywhere in the world. Simulated environments can be tailored to provide realistic training for these missions, and these simulators must be used to maximize training effectiveness while keeping costs low. The research in this area includes simulation training for aviation, VEs for combat training, and new strategies for reserve component training. FY98 products include sensory requirements to train aviation tasks using VE, fidelity requirements for networked aviation systems, methods to enhance the effectiveness of VE training for dismounted soldiers and small units, and an evaluation of the effectiveness of time-compressed gunnery training strategies.

c. Individual//Land Warfare Training

The purpose of this research is to develop innovative and cost-effective training methods and programs that improve a combatant's ability to employ complex high-technology weapons and equipment and perform effectively in various operational environments. FY98 products include training techniques for increasing soldier effectiveness in night operations, identification of the training implications of land warrior systems, and an improved computer-based foreign language tutor and authoring system enhanced by continuous speech recognition.

d. Battle Command Training

The purpose of this research is to provide strategies and methods to develop effective battle commanders by improving cognitive thinking and problem-solving skills required by new mission demands. This research will develop measures of battle command skills and identify those skills and characteristics needed by battle commanders in the 21st century.

e. Technology Programs for Improving Personnel Performance

The objective of this research is to maintain and enhance the quality of the Army by providing effective recruiting, selection, and assignment strategies; improved personnel support systems; and feedback strategies needed to foster a positive command climate. This research will produce an initial set of performance requirements for future noncommissioned officers (NCOs), methods to improve Special Forces team performance, determination of post-mobilization effects of Operation Joint Endeavor upon reserve component soldiers, and techniques for assessing the Army's current command climate.

f. Other Training Modernization Programs

The Army's personnel performance and training S&T program support these activities as well as the majority of the battle labs' advanced warfighting experiments.

DARPA Simulation in Training for Advanced Readiness (SIMITAR) ATD. SIMITAR was initiated to address training readiness issues identified during mobilization for Operation Desert Shield. Results led to congressional interest and funding (FY93–97) for DARPA-led research on advanced technology training for the Army National Guard (ARNG). The effectiveness of SIMITAR training technologies will be validated in two ARNG brigades in FY97–98.

5. Relationship to Modernization Plan Annexes

Table III–41 shows the correlation between Army Training SU / ACs and other AMP annexes.

Table III–41. Correlation Between Training S/SU/ACs and Other AMP Annexes

System/System Upgrade/Advanced Concept		Mounted Forces*	Close Combat Light*	C^4	Engineer & Mine Warfare*	Tactical Wheeled Vehicles*	Fire Support	Space & Missile Defense	IEW	Logistics	Soldier Systems	Aviation	NBC	Combat Health Support	Space
System Upgrade	Distributed Interactive Simulation			●			●		●	●					
	Combined Arms Training Strategy	●	●	○	●		●	●	○	○		●			
	Combat Training Centers	○	○	○	○	○	●	●	●			●			
	Nonsystem Training Devices	●	●	○	●	○	●	●	○		○	●	●	●	○
	Range Instrumentation/Targetry and Devices	●	●	○		●					○				
	Combined Arms Tactical Trainer	●	●	○	●		●	●	○	○		●			
	Family of Simulations			●					●	●					
Advanced Concept	Distributed Models/Simulations for Joint/Theater Exercises	●	●	●	●	○	●	●	○	○	○	●			
	Innovative Simulation-Based Training Strategies	●	●	●	○	○	●	○	○		○	●			
	Advanced Assessment Technologies	○	○	○			○	○	○		●	○			

* See Combat Maneuver Annex.
● System plays a significant role in the modernization strategy
○ System makes a contribution to the modernization strategy

Q. SPACE

As military planners grapple with myriad challenges in 21st Century Warfare, the importance of using space to achieve the ultimate goal—full spectrum dominance—is becoming abundantly clear.

Lieutenant General Edward G. Anderson III

1. Introduction

Space is the fourth medium of warfare, along with land, sea, and air. Space commerce is becoming increasingly important to the global economy. Likewise, the importance of space capabilities and space power to military operations is increasing immensely. Just as land dominance, sea control, and air superiority have become critical elements of current military strategy, space superiority is emerging as an essential element of battlefield success and future warfare. An agreement between U.S. Army TRADOC and U.S. Army Space and Missile Defense Command (SMDC) established the Space and Missile Defense Battle Laboratory (SMDBL) and designated it the specified proponent for space activities. In that regard, the SMDBL will interact with TRADOC schools and battle laboratories for efforts and issues related to space. The control and protection of military, civil and commercial space systems will become paramount to achieving full-spectrum dominance now and in the 21st century.

Space capabilities are critical enablers to achieving information dominance and to ensuring full-spectrum dominance across all levels of conflict. The space science and technology challenge is to determine how to exploit, leverage, and integrate horizontally the military, civil, and commercial space technologies and capabilities into the current force, the programmed force (Army XXI) and the potential force (*Army After Next*). The program for space S&T leverages technology developments from other services as well as government agencies, industry, and academia. Space technology will be an enabler to accelerate the attainment of essential and leap-ahead capabilities required for full-spectrum dominance.

The Army is evolving to meet space needs that are documented in the *Joint Vision 2010, Army Vision 2010,* and *U.S. Space Command Vision for 2020,* and insights emerging from the *Army After Next* process. It has a vision to provide the warfighter with space products that will allow land force dominance in the 21st century, and provide space-based capabilities that are adaptable and deployable to meet the Army's force projection requirements. The Army is developing technologies in areas such as communications, position/navigation, intelligence, surveillance, target acquisition, mapping, weather, and missile warning that support these visions and support the Army's goal of developing space products that get the right information to the warfighter at the right time.

The Army RDA focuses on relevant space capabilities and technologies to support the Army modernization strategy and investment plans. This ensures that essential space technologies are developed and integrated into the current and programmed force to maintain the required overmatch capabilities against potential adversaries. Additionally, guidance is provided for supporting the potential force with leap-ahead space technologies and capabilities required for full-spectrum dominance.

2. Relationship to Operational Capabilities

Table III–42 summarizes space system capabilities. The systems and system upgrades column indicates relatively near-term capabilities, and the advanced concepts column refers to far-term capabilities. The table also shows the correlation between the S/SU/ACs and the Army modernization objectives.

3. Space Modernization Strategy

The modernization of Army space systems is discussed in Annex N of the AMP. The space modernization must be capabilities based and

Table III–42. Space System Capabilities

System/ System Upgrade/ Advanced Concept Function	Patterns of Operation: Project the Force	Protect the Force	Gain Information Dominance	Decisive Operations	Shape the Battlespace	Sustain the Force	System/ System Upgrade Capability	Advanced Concept Capability
COMMUNICATIONS							Digital battlefield communications terminal upgrades	SATCOM on the move
System Upgrade								High-capacity voice, data, and video transmission
Single-Channel Antijam Man-Portable Terminals	●	○	●	●	○	○	SATCOM pages	
Communications	●	○	●	●	○	○	Forward area communications beyond line of sight	
Advanced Concept								
Communications Transport	●	○	●	●	○	○		
Advanced Sensor Collection and Processing	●	○	●	●	○	○		
POSITION/ NAVIGATION	●	○	●	●	●	○	Improved weapons pointing	1-mil pointing accuracy using GPS
INTELLIGENCE SUPPORT (Collection & Processing)							Improved situation awareness	Target geolocation <80 meters
System							Improved targeting	Tactical direct downlinks
Eagle Vision II	○	●	●	●	●	○	Improved pointing accuracy	Tactical direct sensor tasking
Surveillance Targeting and Reconnaissance Satellite	○	●	●	●	●	○	Terrain analysis	Data exfiltration
System Upgrade							Precision strike	Hyperspectral imagery processing
Tactical Exploitation of National Capabilities	○	●	●	●	●	○		
THEATER INTELLIGENCE SUPPORT	●	○	●	○	○	○	Satellite direct access	Theater direct access terminals
THEATER MISSILE DEFENSE								
System								
Joint Tactical Ground Station	●	●	●	●	○	○		
System Upgrade							Real-time warning to theater forces	
TMD Weapons	●	●	●	●	●	●	Target location	
							Laser boresight	
							Pager warning to troops	
SPACE CONTROL	●	●	●	●	●	●	Antisatellite system capabilities	EW, DEW, and KEW systems

● Provides significant capability ○ Provides some capability

focused on enhancing current satellite systems through more effective use of equipment and on influencing new satellite designs to provide significant value added and improved capability for the warfighter. The Army's space modernization efforts support the Army's modernization objectives, as illustrated in Table III–42. As our potential adversaries continue to acquire modern technology to enhance their capabilities, it is clear that the Army's access to and exploitation of space capabilities must be upgraded through a continuous modernization program. Inserting or embedding highly advanced space technologies into Army systems can ensure maintaining combat overmatching. These long-term needs will be met by efforts that are planned and programmed today.

To facilitate effective modernization, it is important that the Army RDA process consider the incorporation of space and space-based assets when looking for solutions to Army warfighter requirements. The Army uses these approaches in its strategy of space RDA:

- Use Army laboratories, schools, and battle labs to evaluate and understand future operational capabilities, advanced operational concepts, and potential technological advances.
- Influence the space design of other services, government (national, civil, and DoD), and commercial space systems to support Army patterns of operations.
- Integrate horizontal technology of space technologies and capabilities to sustain current overmatch capabilities.
- Exploit and leverage existing space technologies, capabilities and systems, government (national, civil, and DoD), commercial, and foreign to field leap-ahead capabilities necessary for full-spectrum dominance.

The Army's focus for technology development in modernizing its space segments is to exploit space and provide relevant space capabilities to the warfighter. The Army's in-house R&D primarily focuses on the ground segment of space systems and communications systems (i.e., receive terminals, antennas, and processors). Many Army R&D institutions are able to bring technology initiatives to the warfighter. They have ongoing programs working in the area of sensor development, algorithm development, and processing to aid in automatic target recognition, battlefield visualization, and theater missile defense applications. The key to Army success is proof-of-concept demonstrations that can show applications for use in an effective architecture for space.

The Army's space-related research, development, and acquisition programs are focused on providing several capabilities to the warfighter through:

- Sensors that are multifunctional and leverage commercial technology.
- Processors that serve to decrease the decision cycle, provide processing in-theater with rapid access to stored data, provide automatic/aided target recognition, and also provide advanced decision aids to include AI attributes.
- Assured access to medium- and high-data rate satellite communication—commercial and national.
- Multiband and in-theater injection Earth terminals.
- Integrated seamless information exchange across strategic and tactical domains, and including dynamic bandwidth allocation.
- Space control efforts to deny enemy information on friendly capabilities while protecting our space assets.
- Obtaining target signatures of interest during day/night operations capable of penetrating weather and concealment.
- Accurately measuring and predicting environmental conditions over areas of interest.

- Integration of space capabilities into modeling and simulation.
- Identification of friend, foe, and neutral forces.
- Providing theater missile attack warning and cueing to friendly forces and allies.
- Providing real-time, survey-quality pointing accuracy for directional systems, to include weapon systems.
- Real-time, direct downlinking of raw and onboard processed data from space-based assets to tactically deployed units that are equipped to process and exploit data.
- POS/NAV devices to navigate accurately across highly uniform terrain areas (jungle and desert).
- Providing technical and procedural applications derived from space assets and products for effective conduct of information operations.
- Providing warning of hostile and friendly fires from artillery and tactical missiles in near real time to effect counterfire or evasion.
- Providing warning to TMD and air defense systems of ducting and false target ranges caused by thermal layering and other atmospheric and stratospheric phenomena.
- Direct tasking of national systems.
- Improvement and integration of more advanced, automated, integrated precise elevation and geographic positioning generation capabilities from national systems at the tactical level for immediate targeting support.

These capabilities support several TRADOC battle laboratory operational capability requirements and Army modernization objectives that have been integrated into the Army XXI process. They include exploratory and advanced technology development space applications that add value to battlefield operating systems. This technological development process provides added value to the current Army acquisition strategy for space-related materiel developments. The acquisition strategy includes leveraging S&T from other services and agencies, using nondevelopmental items (NDIs) and COTS equipment, prototype equipment, and commercial, civil, and tactically oriented satellites to improve warfighting capabilities. ATDs, ACTDs, and STOs have incorporated space-based capabilities. These include communications, position/navigation, intelligence, surveillance, target acquisition, missile warning, and space control.

In the near term, part of the space modernization strategy is to leverage, buy, and exploit commercial and military systems, terminals, and receivers for application on current satellite systems. This strategy includes defining requirements and focusing technologies to influence future applications of planned systems, as well as the design and development of future satellite systems to satisfy Army requirements. For example, the Army is in a cooperative effort with the National Reconnaissance Office (NRO) to develop and deploy the prototype Eagle Vision II van to provide in-theater direct downlink of five commercial imaging satellites. The Army is also the primary participant in the DARPA tactical SAR project, the Surveillance Targeting and Reconnaissance Satellite (STARLITE). The Army is working with NASA and the Air Force to exploit the NASA Lewis and Clark spacecrafts for Army applications. Additionally, the Army has participated in the development of systems requirements for at least three Air Force programs: (1) Space-Based Infrared Systems (SBIRS), (2) Global Positioning System (GPS) III, and (3) Warfighter–1, a hyperspectral demonstration program. The Army's active involvement within the early phases of these programs helps to ensure that Army warfighting requirements are addressed during the critical phases of the design of these systems.

4. Roadmap for Space Systems

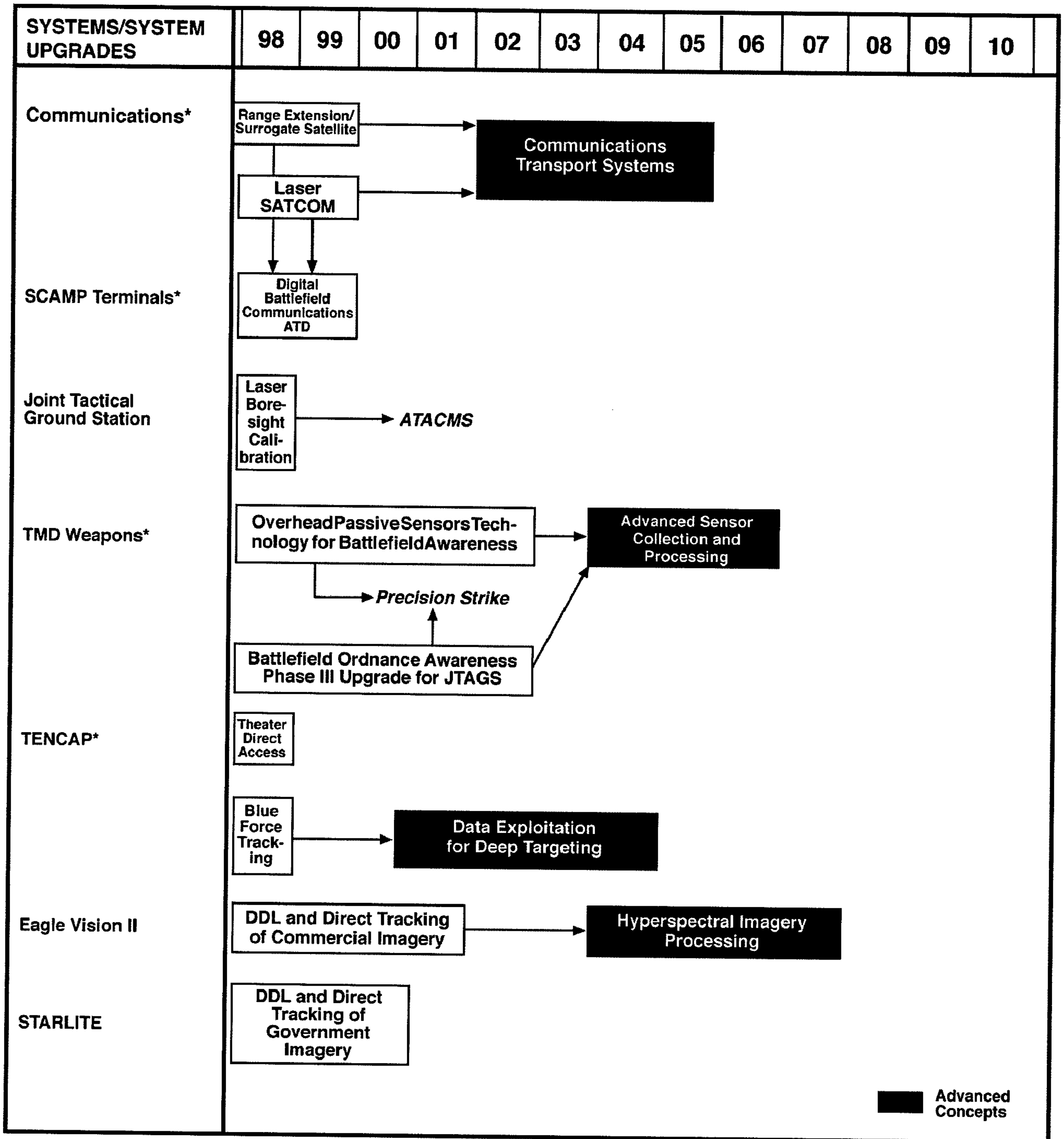
A number of projects are ongoing for the application and development of technologies to exploit space to meet Army requirements. The roadmap for space exploitation is shown in Figure III–23. Table III–43 lists the ATDs, TDs, and S/SU/ACs for space exploitation.

Overhead Passive Sensor Technology for Battlefield Awareness TD (1994–02). This STO will demonstrate several technologies to be used in the collection of multispectral and hyperspectral imagery for the exploitation of remote earth sensing imagery. It has applications in the areas of reconnaissance, surveillance, and intelligence, as well as terrain analysis. The collection sensors will be used to develop the database required to identify spectral signatures for future exploitation. The prototype sensor will demonstrate Army tactical utility in ground and flight tests. Phenomenology between spectral and polarization will be investigated for detection and identification of tactical targets. These sensors will assist in the development of Army requirements for the next generation of remote Earth sensors. Sensor technology will transition to Army sensor packages, to UAV, or to space systems. *Supports:* Precision Strike, TMD Weapons, Advanced Sensor Collection and Processing, Depth and Simultaneous Attack Battle Lab, SMDBL, and Field Artillery Systems.

Battlefield Ordnance Awareness (BOA) TD (1996–02). This STO will demonstrate a near-real-time ordnance expenditure reporting system using space/airborne sensors with onboard processing. This technology will enable battlefield visualization based on both enemy and friendly ordnance expenditures as well as ballistic and cruise missile launches. The display of this information will enable the theater commander to view the development of the battlefield from a revolutionary new perspective. It addresses the need to target ordnance delivery for counterfire purposes, a major battlefield deficiency. The BOA capability will identify the ordnance by type and provide position information for counterfire opportunities, as well as battle damage assessment, blue forces ordnance inventory, information needed to dispatch logistical and medical support, and search/rescue. Advanced processor technology will be used with state-of-the-art focal plane staring arrays to provide critical information to the commander. In FY98, near-real-time processing of ordnance data will be demonstrated. This will be followed in FY99 with the development of a space qualifiable sensor design with state-of-the-art, near-real-time onboard processing. In FY00, the BOA sensor and near-real-time processor will be integrated into a suitable airborne platform with ordnance data collection occurring in FY01. *Supports:* TMD Weapons, Phase II upgrades for JTAGS, Depth and Simultaneous Attack Battle Lab, SMDBL, Precision Strike, Advanced Image Processing, and Field Artillery Systems.

Laser Boresight Calibration TD (1995–98). This STO will develop a solid-state laser calibration capability that will provide a known ground registration point for space-based sensors, resulting in improved launch point predictions and impact area for theater ballistic missiles (TBMs). It will reduce the command and control timelines and improve the overall responsiveness of the Joint Precision Strike and theater area defense forces by significantly reducing the search box. The improved line-of-sight target accuracy will result in higher quality missile warning, alerting, and cueing information. This capability will potentially be integrated into the Joint Tactical Ground Station (JTAGS) P^{3}I. *Supports:* TMD–JTAGS, Army Tactical Missile System (ATACMS), and SMDBL.

Laser Satellite Communications TD (1995–99). This STO is communications technology that will provide a high-bandwidth data rate (overhead and ground) sensor capability while reducing size, weight, power, and cost requirements. Being extremely difficult to jam, it has a low probability of intercept. In FY95, a mountain-top-to-mountain-top demonstration was conducted in Hawaii, which successfully established the acquisition and tracking of a long-range,



*System upgrades.

Figure III–23. Roadmap—Space Systems Modernization

Table III–43. Space Demonstration and System Summary

Advanced Technology Demonstration	Technology Demonstration
Digital Battlefield Communications (see C^4)	Theater Direct Access
	Overhead Passive Sensor Technology for Battlefield Awareness
	Laser Satellite Communications
	Battlefield Ordnance Awareness
	Laser Boresight Calibration
	Range Extension
	Blue Force Tracking (Grenadier Beyond Line-of-Sight Reporting and Tracking)
	Eagle Vision II (Commercial Imagery Satellite)
(For additional information, see Volume II, Annex B.)	STARLITE (Government Imagery Satellite)
System/System Upgrade/Advanced Concept	
System	**Advanced Concept**
Joint Tactical Ground Stations	Communications Transport
Eagle Vision II	Advanced Sensor Collection and Processing
Surveillance Targeting and Reconnaissance Satellite	Data Exfiltration for Deep Targeting
System Upgrade	Hyperspectral Imagery Processing
Single-Channel Antijam Man-Portable Terminals	
Communications	
Tactical Exploitation of National Capabilities	
Theater Missile Defense Weapons	

duplex, high-data-rate LASERCOM link while subjected to a U–2 maneuver/vibration profile. A follow-on study, which began in FY96, evaluated the feasibility of using LASERCOM in space-to-ground applications. It was completed in FY97 and revealed that a layered architecture consisting of satellite-to-air (i.e., manned and unmanned) air-to-ground platforms provided high link availability through most weather conditions, especially for those missions with larger response time requirements. An air-to-ground proof-of-concept demonstration was initiated in FY97 using the Airborne Surveillance Testbed and existing Ballistic Missile Defense Organization (BMDO) LASERCOM terminals. FY97 also saw the development of a portable ground LASERCOM terminal, which will be part of a satellite-to-ground demonstration in FY98 using the space technology research vehicle 2 (STRV–2) satellite. The satellite is scheduled to be launched during the 4th quarter of FY98, and will transmit data at 1.2 GBps using two LASERCOM portable ground terminals. Future demonstrations will support the establishment of a Joint LASERCOM Internet Concept that meets the needs of the warfighter in Force XXI. *Supports:* Digital Battlefield Communications ATD, Communications Transport System, and SMDBL.

Digital Battlefield Communications (DBC) ATD (1995–99). The DBC ATD will exploit emerging commercial communications technologies to support multimedia communications in a highly mobile dynamic battlefield environment, the "digitized" battlefield, and split-based operations. Commercial ATM technology will be integrated into actual tactical communications networks to provide bandwidth on demand to support multimedia information requirements. It is discussed in detail in the section on Command, Control, Communications, and Computers (above).

Range Extension TD (1994–99). The goal of this demonstration is to support Army C^4I modernization by developing and demonstrating key technologies and capabilities for flexible and

affordable intra-theater long-range communications. It includes the use of surrogate satellites, enhancements to current SATCOM equipment, and UAV cross links. Major technology areas to be addressed are airborne payload designs, ground terminal adaptations, interoperability/compatibility, and simulation. These technologies will be used to supplement current (and programmed) SATCOM resources at all frequency bands. SATCOM terminals will be extended by improvements to reduce size and weight, increasing throughput and mobility and implementing emerging techniques such as DAMA. This demonstration is referenced further in the section on Command, Control, Communications, and Computers (above). *Supports:* Digital Battlefield Communications, JPO UAV TIER II Program, and Communications Transport System.

Theater Direct Access TD (1995–98). A tactical satellite launched by DARPA will be used to conduct a proof-of-concept technology demonstration with Army TENCAP systems to show the capability of satellite mission tasking direct from theater forces. The joint Army/DARPA/NSA program will conduct the technology demonstration of this concept in support of early entry and battle command doctrine. *Supports:* Tactical Satellite system and system upgrades to Army TENCAP.

Blue Force Tracking (Grenadier BRAT) TD (1996–98). This is the Army's application of the National Reconnaissance Office's collection of broadcasts from remote assets (COBRA) activity. In the Army, Grenadier BRAT (GB) is being evaluated as a Blue Force tracking tool for integration into the Army's overall battlefield visualization efforts. The system uses a spread-spectrum, LPI signal compatible with national support systems. This waveform is the carrier for the GB data and carries location data provided by an integrated GPS receiver as part of the transmitter, a unique identifier, and selected unit status information. At preset intervals, the information is transmitted and collected by way of national support systems. It is processed by a single rack of equipment at the ground processing center and injected into tactical receiver equipment and related applications or tactical information broadcasting system (TIBS) broadcasts. The data are received by any TRAP/TIBS-compatible receiver and displayed as an unidentified signal. Army TENCAP systems have been provided software that allows the operator to display the data in graphical situation display format and pull down the unit identification and status data. These data are then passed to the Army battlefield control system for integration as part of the operational battlefield visualization. *Supports:* Army TENCAP and Data Exfiltration for Deep Targeting.

Eagle Vision II TD (Direct Downlink (DDL) and Direct Tasking of Commercial Imagery Satellites) (1998–01). Eagle Vision II (EV–II) will provide a direct downlink of unclassified remote sensed imagery from commercial satellites to the supported commander. It will take direct downlink from a baseline of five commercial satellite vendors. These data will be processed and provided to users in standard image formats for command and control, mission rehearsal, intelligence, and geographic information systems. EV–II will consist of an air- and sea-transportable 30-foot expando van containing a data acquisition segment and data integration segment and a 5-meter X-band antenna. It provides near-real-time unclassified commercial imagery from a baseline of five commercial vendors of multispectral and panchromatic imagery. The demonstration will pass imagery to a digital terrain support system for terrain analysis and digital terrain elevation data level 1 and 2 data generation. It will also pass the RISTA systems such as the modernized imagery exploitation system for intelligence exploitation. *Supports:* Eagle Vision II and Hyperspectral Imagery.

Surveillance Targeting and Reconnaissance Satellite (STARLITE) TD (DDL and Direct Tasking of Government Imagery Satellites) (1998–00). STARLITE is a program that will provide a direct tasking control and downlinking of a small, lightweight imaging satellite to a deployed tactical/operational commander. It will use a SAR for all-weather, day/night operations in a

constellation of 24 satellites projected for launch in 2003–2005. This will allow near-continuous coverage of the battlefield or contingency area to the depth of 800–1,000 miles, with 90 percent confidence of a 15-minute response time from request to image delivery to the commander. The STARLITE demonstration will have two satellites downlinking to a modified Army Space Program Office (ASPO)-enhanced tactical radar correlator (ETRAC). The ETRAC modification will consist of a clip-on kit usable in the four services' common imagery ground/surface systems, such as Tactical Exploitation System (TES), contingency airborne reconnaissance system (CARS), tactical exploitation group (TEG), and Navy tactical input segment (TIS). The preliminary objectives for the demonstration are to determine feasibility and utility of delegated collection management authority to a tactical commander, demonstrate imagery DDL using LIGHTSAT technologies, demonstrate rapid-response changes in tasking by an Army corps, and assess the utility of corps directly commanding the payload. *Supports:* STARLITE.

5. Relationship to Modernization Plan Annexes

Table III–44 shows the relationship between the Space S/SU/ACs and AMP annexes.

Table III–44. Correlation Between Space S/SU/ACs and Other AMP Annexes

System/System Upgrade/Advanced Concept		Modernization Plan Annexes						
		Aviation	IEW	Fire Support	Close Combat Light*	C^4	Space & Missile Defense	Logistics
System	Joint Tactical Ground Station		●	○	○	●		
	Eagle Vision II	●	●	●	○	○	●	○
	Surveillance Targeting and Reconnaissance Satellite	●	●	●	○	○	●	○
System Upgrade	Theater Missile Defense Weapons		○			○	●	
	Tactical Exploitation of National Capabilities	○	●	●	○	○	○	○
	Single-Channel Antijam Man-Portable Terminals		○	○	○	●	○	○
	Communications		○			●		
Advanced Concept	Communications Transport	○	○	○	○	●	○	○
	Advanced Sensor Collection and Processing	○	●	○	○	○		
	Data Exfiltration for Deep Targeting	○	●	●		○		
	Hyperspectral Imagery	●	●	●	○	○	●	○

* See Combat Manuever Annex.
● System plays a significant role in the modernization strategy
○ System makes a contribution to the modernization strategy

CHAPTER IV

TECHNOLOGY DEVELOPMENT

CONTENTS

CHAPTER IV

TECHNOLOGY DEVELOPMENT

Military operations in the 21st century will be dramatically different from those in the past. They will be characterized by technological sophistication, speed, and complexity

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Deputy Chief of Staff for Logistics

A. INTRODUCTION

This chapter reflects the Army's investment in implementing its post-cold-war science and technology (S&T) vision and strategy, as described in Chapter I, "Strategy and Overview," and in Chapter II, "Training and Doctrine Command's Role in Science and Technology." It addresses the Army's 6.2 investment strategy, and is presented as 19 technology sections that are adapted from the subarea architecture of the *Defense Technology Area Plan* (DTAP). A crosslink between the defense technology areas and the chapter sections is provided in Table IV–1.

Table IV–1. Defense Technology Areas/ Chapter IV Taxonomy

Defense Technology Area	Related Chapter IV Section
Air Platforms	Portions of Air Vehicles Portions of Aerospace Propulsion and Power
Chemical/Biological Defense and Nuclear	Chemical and Biological Defense
Information Systems Technology	Command, Control, and Communications Computing and Software Modeling and Simulation
Ground and Sea Vehicles	Ground Vehicles
Materials/Processes	Materials, Processes, and Structures Civil Engineering and Environmental Quality Manufacturing Science and Technology
Biomedical	Medical and Biomedical Science and Technology
Sensors, Electronics, and Battlespace Environment	Sensors Electron Devices Battlespace Environments
Space Platforms	Portions of Air Vehicles Portions of Aerospace Propulsion and Power
Human Systems	Human Systems Interface Individual Survivability and Sustainability Personnel Performance and Training
Weapons	Conventional Weapons Electronic Warfare/Directed Energy Weapons

A new feature in this chapter is the linkage of each technology section with the Training and Doctrine Command (TRADOC) integrated and branch/functional unique future operational capabilities (FOCs). The FOCs were developed in 1996/97 to provide a warfighting focus for Army S&T planning and they supersede the operational capability requirements (OCRs) that were used in prior year master plans. A listing of the FOC linkages can be found within each technology section. A more complete description of the TRADOC FOCs is given in Volume II, Annex C, of this plan.

The Army's basic research, applied research, and advanced technology development work balance a strong emphasis on technologies that could upgrade currently fielded systems. There is also a continuing assessment of long-range insights and requirements as may be offered by future-seeking initiatives such as the *Army After*

Next (AAN). This approach maintains an operational edge for the near term while simultaneously developing technologies that will ensure future land force dominance in the mid to far term. The thrust of the Army investment is to capitalize on technology opportunities, reduce technology barriers, and exploit emerging technology options for essential battlefield capabilities—as defined by our warfighters.

The Army investment in technology development enables advanced concepts for land combat, and constitutes the critical link between the Army's basic research thrusts, as described in Chapter V and the *Army Modernization Plan* (AMP) annexes and roadmaps, as presented in Chapter III.

B. STRATEGY

The Army 6.2 program identifies and focuses on selected technologies that will provide the maximum warfighting capability for every dollar invested. This demands a significant dual commitment to in-house Army applied research and to the expansion of cooperative efforts with the other services and industry. The Army leverages research and technology opportunities in academia, industry, and the international community to promote efficiency and synergy at all levels. In particular, the Army Research Laboratory (ARL) implementation of the federated laboratory concept plays a significant role in this strategy. The technology leveraging and transfer program is discussed more fully in Chapter VII.

The Army S&T oversight process, as described in Chapter I, prioritizes technology needs and opportunities based upon their potential to provide critical battlefield capabilities. These capabilities are jointly defined by the combat and materiel developers. The early and continuous involvement of the warfighter in the S&T capabilities definition process allows for a balanced look at the "technology push" coming from the Army's S&T community and the "requirements pull" prompted by the needs of the warfighter. A mechanism that promotes this alignment is the interplay between the combat and materiel developers that occurs during the Army Science and Technology Objective (STO) reviews and the TRADOC S&T reviews. Both occur in the spring, and result in an S&T program that is attuned to the warfighter's evolving vision of the future (e.g., Force XXI, *Army After Next).*

Studies by the National Research Council's Board on Army Science and Technology (BAST) Study on Strategic Technologies for the Army of the 21st Century (STAR) panel, the Defense Science Board (DSB), the Army Science Board (ASB), the Army's in-house S&T community, and the TRADOC battle laboratories and schools have all recommended that Army S&T focus on "critical" technologies. The Army 6.2 investment reflects this commitment to eliminate the barriers that impede technological opportunities presented by the most promising state-of-the-art advances. While its main focus is providing capabilities for land force dominance, the Army investment is also aligned with the Department of Defense (DoD) strategy as summarized in Chapter I.

Each section in this chapter is structured to define the area of technology, summarize the Army's ongoing technological work, and provide a forecast of future capabilities. The years shown on each technical objectives table approximate key aspects of the planning, programming, budgeting, and execution system (PPBES) process timetable. FY98–99 relates to the budget years. FY00–04 addresses the program objective memorandum (POM) time period, and FY05–13 covers the Army research, development, and acquisition (RDA) Plan. The Army STOs that are associated with this chapter can be found in Volume II, Annex A.

C. AEROSPACE PROPULSION AND POWER

1. Scope

Advanced propulsion and power technologies provide the muscle for Army land combat systems. Toward that end, the Army aerospace propulsion and power technology area includes aircraft propulsion systems and components that are more compact, lighter weight, higher horsepower, more fuel efficient, and lower cost than those currently available. It also includes compact, lighter weight, lower cost, and longer duration aircraft and space vehicle power generation and transmission systems and their components, including primary power transmission for rotorcraft. In addition, it includes associated advanced fuels and lubricants.

Aerospace propulsion and power excludes efforts directed toward generic materials, which are included in Section IV–P, "Materials, Processes, and Structures." It also excludes moderate- to large-scale manufacturing process development, which is included in Section IV–T, "Manufacturing Science and Technology." While there is similarity between gas turbines used for rotorcraft propulsion and those used on missiles, missile propulsion encompasses more than just the gas turbine field. Due to the larger amount of commonality between missile and conventional weapon propulsion systems, missile propulsion is discussed in Section IV–I, "Conventional Weapons."

2. Rationale

Army aerospace propulsion and power technology programs are key enabling elements of the AMP, feeding directly into (1) upgrading existing systems, (2) conducting development, and (3) supporting advanced concepts, as discussed in Section III–D. In addition to their contributions to the battle laboratory warfighting capability, these technologies will enable Army XXI to project the force, to protect the force, and to sustain the force. Longer term elements of the aerospace propulsion and power technology program form the required foundation for large reductions in fuel dependence, which are key to AAN planning.

Army aerospace propulsion and power technology is developed in close coordination with the Air Force, Navy, Defense Advanced Research Projects Agency (DARPA), NASA, and industry, thus inherently promoting dual-use technologies and processes. Despite budgetary constraints, the joint Army, Air Force, and Navy programs, leveraging of NASA resources, and substantial use of cooperative agreements with industry have achieved significant progress. As a result, both the civilian industry and the military industrial base are strengthened and development is faster, more efficient, and less costly. In-house Army laboratory expertise is needed to ensure that those technologies unique to Army applications are addressed and to perform the high-risk, longer term technical investigations, research, and development that ensure attainment of Army objectives and ensure that the Army continues to be a smart buyer. The overall cost to the taxpayer for joint ventures beneficial to both military and civilian applications is therefore minimized.

3. Technology Subareas

a. Rotorcraft Propulsion

Goals and Timeframes

Under the integrated high performance turbine engine technology (IHPTET) program, the Army, Air Force, Navy, NASA, DARPA, and industry are working together to reduce specific fuel consumption of gas turbines by 40 percent, to increase the power-to-weight ratio by 120 percent, and to reduce production and maintenance costs by 35 percent for future engines (compared with current capability) by FY03, STO IV.C.01. While this is an integrated effort of many organizations, the requirements of small turbomachines dictate that the Army emphasize component technology development that is unique to Army turboshaft engines.

This enhanced propulsion capability will significantly improve Army rotorcraft range and payload characteristics starting in the year 2000. (IHPTET technology will also be applicable for ground vehicles.) An advanced concepts (or IHPTET IV) activity has begun with the goal of defining the path for gas turbine propulsion technologies and challenges beyond IHPTET Phase III.

Major Technical Challenges

Challenge—Attainment of Phase III joint turbine advanced gas generator (JTAGG) goals requires a very high compressor pressure ratio and high rotational speed. Using current practices, a robust, high-pressure ratio compression system would require multiple stages, adding complexity and weight. In addition, the stresses resulting from the combination of compressor exit temperature and rotational speed goals exceed the capabilities of current material.

Approach—Apply evolving compressor design tools and materials to design, fabricate, and test axial and centrifugal compressor stages to provide a validated methodology for attaining the JTAGG III compression system goals in two stages. Develop an active compressor stability control system to expand the usable compression system operating range.

Challenge—The future generation combustion system must accept inlet air at very high temperatures and pressures, accomplish nearly stoichiometric combustion in a small volume with low emissions, and deliver products of combustion to the turbine with an acceptable temperature uniformity. This is to be accomplished in a robust, affordable, lightweight compact combustor with improved operability over a very wide operating range.

Approach—Develop advanced technologies, including three-dimensional (3D) steady and unsteady computational codes, new materials and fabrication techniques, total thermal management, and novel combustion stabilization techniques to enable accomplishment of JTAGG III combustion system goals for turboshaft engines.

Challenge—Critical to the attainment of Phase III JTAGG will be the development of high work, lightweight turbine systems that operate at significantly increased turbine inlet temperatures. High performance must be delivered with minimal or no cooling in a temperature environment more severe than in current turbines. What cooling air is available for use will also be at higher temperature.

Approach—Apply high strength, high temperature, low-density materials that allow operation in a high temperature environment with minimal or no cooling. Materials under consideration include monolithic ceramic or intermetallic composites for the turbine vanes and blades. Enhance analysis tools to include 3D steady and unsteady computational codes to provide a better understanding of the aerodynamic and heat transfer mechanism in extremely complex airfoils. Configure turbine disks with a dual alloy or dual microstructure to tailor material characteristics with bore and rim mechanical requirements. Develop innovative techniques to attach blades made of nontraditional materials to disks in the high rotational stress, high temperature environment of Phase III JTAGG turbines.

Challenge—Gas turbine engine mechanical components of Phase III JTAGG engines and beyond must support the mechanical, thermal, and rotational loads imposed by the extremely high operating temperatures, pressures, and speeds required by the thermodynamic cycle. Bearing, seal, lubricant, and material requirements all simultaneously exceed existing system capabilities significantly. Failure to meet technology goals for mechanical components would prohibit attainment of IHPTET Phase III and advanced concepts goals.

Approach—Of all the phase III IHPTET goals, those for mechanical systems are the most universally applicable across engine types. For this reason, the Army will continue to leverage the overall government-industry IHPTET mechanical components research team's attention to

turboshaft engine needs. Extend successes in basic research to investigate development of higher temperature lubricants and advanced bearing materials. Army, Air Force, Navy, NASA, and industry magnetic bearing developments will be extended to higher temperatures. Magnetic bearing systems enable reduced parasitic losses, minimization/control of tip clearances, active health monitoring for increased performance, reliability, and maintainability. Investigate materials and design innovations for application to shaft designs with high bending stiffness and high-strength capability in a small diameter.

b. Rotorcraft Drives

Goals and Timeframes

Through integration of the technological development activities of the Army, Navy, NASA, DARPA, industry, and academia, a 25 percent increase in shaft horsepower-to-weight, a 10 decibel reduction in transmission-generated noise, a 2X baseline mean time between replacements (MTBR) and a 10 percent reduction in production cost will be demonstrated for rotorcraft drives in FY00, STO III.D.03. Goals for 2010 and beyond will extend the power-to-weight ratio goal to 40 percent while reducing noise 15 dB from baseline, holding MTBR steady and reducing production cost 30 percent.

Major Technical Challenges

Challenge—The goals established for the Advanced Rotorcraft Transmission (ART) II, STO III.D.03, present conflicting technical challenges. Standard approaches to noise reduction and life extension would yield weight increases. The challenges, therefore, involve developing analytical tools that would enable the design of components with high strength and low noise, allow the application of advanced lightweight materials with higher strength and increased pitting, scoring and corrosion resistance, system designs with nearly equal load sharing, and minimized lubrication. These components must then be shown to maintain their performance improvement when integrated into a complete drive system. Future systems will incorporate lightweight electric power generation, transmission and drives.

Approach—Validate the performance of advanced gear materials in cooperation with industry and academia by performing rig tests to compare the performance of new materials with benchmarked performance levels of standard gear materials. Fabricate components using newly developed design codes and validate predicted performance improvements on rig tests. Validate system health and usage monitoring tools and noise reduction and prediction codes using system-level tests. Analytical tools are derived from academia and government laboratories; hardware designs are developed with industry, and validation experiments are conducted by industry, academia, or in government laboratories. The totally integrated program focuses resources on the common goals of the government and industry.

c. Fuels and Lubricants

Goals and Timeframes

In fuels and lubricants, the Army's major thrust is in the development and demonstration of new analytical technologies for rapid assessment of both petroleum quality and type, using spectroscopic and chromatographic methods. The technology being developed is to be incorporated into the Army's new petroleum quality analysis (PQA) system.

Major Technical Challenges

The new analytical methods will enable significant reductions in the operational requirements for petroleum testing in the field (i.e., 50 percent less manpower, 70 percent reduced testing time, and 60 percent less test hardware). The technical challenges encompass compressing the testing time, developing improved detection systems, reducing the size of the associated components, correlating test results, and developing expert systems for applying corrective measures.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Aerospace Propulsion and Power is shown in Table IV–2.

5. Linkages to Future Operational Capabilities

The influence of this technology area on TRADOC FOCs is summarized in Table IV–3.

Table IV–2. Technical Objectives for Aerospace Propulsion and Power

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Rotorcraft Propulsion	High-efficiency, high-pressure ratio, dual-alloy centrifugal impellers Characterization of start up process of nontraditional compression system Nonintrusive ignition Turbines with high cooling effectiveness airfoils bonded to pondered metal disk Flight weight magnetic bearing control Nonmetallics for combustor and turbine applications 3.5 million diameter in millimeters x rotational speed ceramic steel roller bearings	Higher temperature inter-/nonmetallics for turbines and combustors Stability enhancement/active surge control concept demonstration Alternate compression system demonstration Metal matrix composites for compression systems application Wide operating range, low pattern factor combustion system 1000° Fahrenheit (F) magnetic bearing Nontraditional seals High stiffness/strength shaft	Unconventional compression, combustion, power producing systems, and arrangements Smart engine concepts demonstration Improved aerodynamic performance small components Shrouded rotating components Alternate concepts for waste energy recovery Advanced lightweight, high temperature materials Supercritical fuel injector
Rotorcraft Drives	Hardened/ground face gears manufactured and rig tested Seeded fault diagnostic/prognostic spiral bevel gear tests	Hardened/ground face gears life and reliability data documentation High-speed gearing thermal behavior validation test Efficient electric components rig test High temperature, lightweight lube system Low noise, lightweight planetary gear system	Nonferrous, hybrid gear, and shaft systems Electric power transmission feasibility demonstration
Fuels and Lubricants	Develop field supportable, fast fuel quality analyzer		

Table IV–3. Aerospace Propulsion and Power Linkages to Future Operational Capabilities

Technology Subarea	Integrated and Branch/Functional Unique Future Operational Capabilities
Rotorcraft Propulsion	TR 97–022 Mobility—Combat Mounted TR 97–035 Power Source and Accessories TR 97–036 Nonprimary Power Sources Combat Vehicles/Support Systems TR 97–037 Combat Vehicle Propulsion
Rotorcraft Drives	TR 97–022 Mobility—Combat Mounted TR 97–035 Power Source and Accessories TR 97–036 Nonprimary Power Sources Combat Vehicles/Support Systems TR 97–037 Combat Vehicle Propulsion
Fuels and Lubricants	TR 97–029 Sustainment TR 97–030 Sustainment Maintenance TR 97–037 Combat Vehicle Propulsion

D. AIR VEHICLES

1. Scope

DoD has assigned the Army as the lead for rotary wing science and technology in aeromechanics, flight control, structures, and subsystems supporting development of military rotary-wing air vehicles. The aviation community is aligning all planning documents to coincide with the DoD Director, Defense Research and Engineering (DDR&E) requirement to establish technological objectives, identify technical barriers, and establish milestones for achievement. Programs will be tracked by Office of the Secretary of Defense (OSD) to these detailed plans. The rotary-wing vehicle subarea is divided into four technology efforts: aeromechanics, flight control, subsystems, and structures. The objectives for each technology effort and the timeframes have been set in accordance with the DDR&E document, *Rotary Wing Vehicle (RWV) Technology Development Approach (TDA),* and are summarized below.

2. Rationale

Rotorcraft have become critically important members of the combined arms team, bringing a degree of deployability, mobility, lethality, and sustainability to the battlefield commander not available with other systems. With the continuing decrease in fiscal resources, affordability and dual use have become increasingly important in shaping Army Aviation's S&T strategy. Technology must support solutions to real world problems, avoiding work that does not provide leap-ahead improvements in system capabilities. This is important to sustaining current systems because fielding new systems is being pushed further to the "outyears." From a dual-use perspective, civilian and military rotorcraft communities have a mutual stake in all but very few areas of rotorcraft technological research, such as reducing the vulnerability of rotorcraft in battlefield environments. Improvements in handling qualities, vibration, and sound level reductions are equally important to civil and military rotorcraft operators. It is estimated that 95 percent of the DoD investment in rotary-wing technology has civil application.

3. Technology Subareas

The air vehicle technology subareas are quantified at milestones of 2000, 2005, and 2010 and they support the systemic improvements articulated by the *Defense Technology Area Plan* (DTAP). These include:

- Reduction in RWV empty weight fraction—7, 15, and 22 percent.
- Increase in cruise efficiency—4, 11, and 20 percent.
- Increase in maneuverability and agility—48, 66, and 112 percent.
- Reduction in RWV maintenance cost—18, 35, and 50 percent.
- Reduction in signature—35, 50, and 60 percent.
- Reduction in development time (2005, 2010 milestones) 15 and 25 percent.
- Reduction in RWV flyaway cost (2005, 2010 milestones) 35 and 50 percent.

a. Aeromechanics

Goals and Timeframes

Work in aeromechanics technology addresses efforts in multidisciplinary phenomena including acoustics, aerodynamic performance, rotor loads, vibration, maneuverability, and aeroelastic stability. Aeromechanics S&T seeks to improve the performance of rotorcraft while reducing the noise, vibrations, and loads inherent to helicopter operation. Efforts are focused on refining analytical prediction methods and testing capabilities, on improving the versatility and efficiency of modeling advanced rotorcraft, and on achieving dramatic advances through concept applications. Attaining the goal of a "jet-smooth ride" in helicopters will greatly enhance public acceptance, along with providing quieter rotorcraft. The goals are set at the component level and the associated milestones are provided in Table IV–4.

Table IV–4. Aeromechanics Objectives

Aeromechanics	Improvement (%)		
	By 2000	By 2005	By 2010
Reduce vibratory loads	20.0	40.0	60.0
Reduce vehicle adverse aerodynamic forces	5.0	12.0	20.0
Increase maximum blade loading	8.0	16.0	24.0
Increase helo/rotor aerodynamic efficiency	3.0	6.0	10.0
Increase prop/rotor aerodynamic efficiency	1.5	3.0	4.5
Increase rotor inherent lag damping	33.0	66.0	100.0
Aeromechanics prediction effectiveness	65.0	75.0	85.0

Major Technical Challenges

Challenge—The inability to accurately predict and control stall and compressibility characteristics of current airfoils and their impact on unsteady loads and the resulting structural dynamic responses.

Approach—Investigate the influence of airfoil profile on development of dynamic stall in compressible flow, quantify influence of compressibility on flow control techniques, and develop innovative ways to use smart materials for flow control and structural response.

Challenge—The inability to accurately predict and control forces caused by viscous and interactional aerodynamics and separated flow.

Approach—Enhance flowfield visual techniques using Doppler global velocimetry; study various models' rotor wake and fuselage pressure distributions using isolated rotor test system. Calculate adverse forces using validated computational fluid dynamics (CFD) and comprehensive analyses. Develop reliable, validated engineering computational codes based on full-potential, vortex embedding techniques to predict rotor performance and loads in all flight regimes.

Challenge—The inability to accurately predict and control stall and compressibility characteristics of current airfoils along the span of the rotor blades and their impact on blade loading limits. The inability to markedly increase maximum outboard blade lift coefficients.

Approach—Develop high dynamic-lift stall-free airfoils with multi-element concepts such as slat, slots, variable leading edges, or boundary layer controls.

Challenge—The inability to predict and control the effect of the rotor wake and blade response on unsteady aeroacoustic loads. Controlling compressibility effects on advancing-blade acoustic sources and propagation phenomena is hampered by the interdependence of numerous parameters that influence noise radiation.

Approach—Develop verified CFD code to predict wake geometry, airloads, and performance for rotor blades, in particular blade-vortex interaction regimes and the resulting aeroacoustics.

Challenge—Identify successful combinations of aeroelastic rotor couplings to increase damping. The constraints include conflicting design requirements, rotary-wing operating regime diversity, and fail-safe reliability requirements.

Approach—Investigate kinematic and smart structures couplings that result in less dependency on separate damping devices. Utilize parametric rotor testing to substantiate prediction fidelity of marginally damped rotor configurations.

Challenge—The lack of solutions to the multidisciplinary rotorcraft system phenomena. Significant difficulty in acquiring high-quality correlation data for validation. Prediction-to-design interface inadequate for complex rotorcraft synthesis.

Approach—Prediction effectiveness attributes defined and composed against data to determine element accuracy. Metrics for improvement shall include quantifiable subelement effectiveness

and system integration value, such as in a product and process development simulation.

b. Flight Control

Goals and Timeframes

Flight control technology defines the aircraft flying qualities and pilot interface to achieve desired handling qualities in critical mission tasks, synthesizes control laws that will facilitate a particular configuration's achieving a desired set of flying qualities, and integrates advanced pilotage systems to the aircraft. Helicopters are inherently unstable, nonlinear, and highly cross coupled. As with many other technologies, the revolution in the power and miniaturization of computers holds tremendous promise in this field, permitting realization of the full potential of the rotorcraft's performance envelope and maintenance of mission performance in poor weather and at night. The objectives are provided in Table IV–5.

Table IV–5. Flight Control Objectives

Flight Control	Improvement (%)		
	By 2000	By 2005	By 2010
Improvement in platform flight path pointing and accuracy (attack only)	50	65	80
Improve external load handling qualities at night (cargo only)	75	185	225
Reduce the probability of encountering degraded handling qualities due to flight control system failures	40	65	90
Improved handling qualities at night with partial actuator authority	CHPR 4*	CHPR 3*	CHPR 3*
Increase in precision maneuvering at extreme load factors	20	35	50

* CHPR = Cooper Harper Pilot's Rating

Through the integration of the vehicle's flight control system with weapons fire control, significant improvement in pointing accuracy will be achieved by the turn of the century and will permit increased use of low-cost, unguided rockets as precision munitions. Further, a significant development cost driver is being assessed. Objectives have been set to: improve external load handling qualities at night with partial actuator authority (from a Cooper Harper Pilot's Rating (CHPR) of 4 to 3) reduce the probability of encountering degraded handling qualities due to flight control system failures 40 percent to 90 percent, and improve the flight path and accuracy by 50 percent to 80 percent. Reduction in flight control system flight test development time should be realized. Time span for accomplishment is from the present through year 2010, with an intermediate milestone at year 2005.

Major Technical Challenges

Challenge—Lack of knowledge of optimal rotorcraft response types (rate, attitude command/attitude hold, translational rate command) and their interactions with load suspension dynamics and load aerodynamics.

Approach—Use piloted simulation and flight test to investigate handling qualities requirements for external loads. Develop appropriate criteria for poor weather and darkness. Extend efforts to address high speed flight and loads with significant aerodynamic interactions.

Challenge—Lack of techniques for sensing the onset of limits, determining appropriate actions, and cueing the pilot or generating automatic interference to permit the pilot to safely, but aggressively, fly the rotorcraft out to the limits of the flight envelope.

Approach—Use analysis and piloted simulation to develop techniques for protecting the pilot from loss of control and avoiding catastrophic failures or reduced fatigue life. Validate critical concepts in-flight, using a variable stability helicopter.

Challenge—Inadequate air vehicle mathematical modeling and flight control system (FCS) design, optimization, and validation techniques. These deficiencies prevent achieving desired handling qualities for advanced configurations

and critical mission tasks, without time consuming iteration during flight test.

Approach—Improve mathematical modeling and simulation fidelity so that new aircraft actually fly as designed. Improve techniques for updating math models and control laws to minimize time required to diagnose and eliminate deficiencies. For advanced fly-by-wire flight control systems, develop simpler redundancy management and software verification and validation (V&V) techniques so that time for making changes can be reduced.

Challenge—Lack of knowledge of optimal functional integration of flight controls, engine fuel control, the weapon systems, and the pilot interface.

Approach—Develop a viable integrated fire and flight control (IFFC) system architecture, conduct manned full-mission simulation, ground demonstration of hardware and software for airborne vehicle application, and flight test demonstration of the IFFC concept.

c. Structures

Goals and Timeframes

Focusing on integrated product and process development (IPPD), rotary-wing structures S&T aims at improving aircraft structural performance while reducing both acquisition and operating costs of the existing fleet of aircraft and future systems. The technical feasibility of load synthesis methods (holometrics, et al.) and regime/flight condition recognition algorithms as means to predicting the actual loads experienced in-flight has been demonstrated; further improvements to the reliability of these methods will enhance the safety, performance, and cost effectiveness of rotorcraft. "Virtual prototyping" of systems to optimize the structural design for efficiency and performance will remove a large portion of the risk in exploring new concepts and rapidly move the most promising concepts to production. The objectives are provided in Table IV–6.

Table IV–6. Structures Objectives

	Improvement (%)		
Structures	**By 2000**	**By 2005**	**By 2010**
Reduction in (structural component weight)/gross weight (GW)	5	15	25
Reduction in structures manufacturing, LH/lb	10	20	40
Reduction in structural component development time	—	25	40
Increased accuracy of structural load predictions	—	75	85
Increased accuracy of in-flight cumulative fatigue damage predictions	—	95	98
Increased displacement capability of smart materials actuator	—	300	500
Reduction in dynamically loaded structure stress prediction inaccuracy	—	30	50

Breakthroughs in these areas will effect improvements in maintenance and production costs, as well as reduce the empty weight fraction of the airframe, while increasing durability, performance, and ride comfort of rotorcraft. In FY97, progress was made in the definition of a structural configuration and its associated metrics for the Rotary Wing Structures Technology Demonstration (RWSTD). This included the determination of advanced structural concepts and appropriate exit criteria. Other accomplishments included the characterization and selection of low cost, embedded cure rheology sensors, and the development of fuzzy logic cure control algorithms. In FY98, the initiatives will include establishing an RWSTD system architecture to integrate distributed design disciplines, knowledge-based design tools and databases for the rapid development of novel structural concepts, demonstrating the use of adhesives to bond and co-cure primary structures in lieu of fasteners, developing analytical methods that will calculate the high impulse crash loads in landing gear fittings, and demonstrating the ability of closed-loop, fuzzy logic cure process control, using

in-situ rheology measurements, to adapt to material and process variations.

Major Technical Challenges

Challenge—Lack of knowledge about and accurate methodologies for flight regime recognition algorithms for determining the rotorcraft flight conditions from state parameters in a dynamic environment. Lack of knowledge about and accurate methodologies for the synthesis of strains/loads from other measured parameters and loads in a dynamic environment. Limited fatigue life and durability of load/strain measuring sensors in a dynamic operational environment.

Approach—Develop and refine flight regime/flight condition recognition and load synthesis algorithms based on aircraft state parameters and other measured loads. Conduct bench and flight test evaluations on instrumented aircraft to validate accuracy. Collect operational data over a period of 1–3 years to validate the reliability of the flight data recorder and the algorithms.

Challenge—Lack of knowledge of accurate algorithms for determining the rotorcraft flight condition from state parameters in a dynamic environment.

Approach—Develop and refine regime/flight condition recognition algorithms based on aircraft state parameters. Conduct bench and flight test evaluations on instrumented aircraft to validate accuracy. Collect operational data over a period of 1–3 years to validate the reliability of the flight data recorder and regime/flight condition recognition algorithms.

Challenge—Inability to sense and measure rheological behavior of materials during cure, lack of optimization techniques to minimize scrap, insensitivity of embedded sensors for adaptive control of cure cycle, lack of defect characterization and impact on structural performance, lack of process simulation models, ineffective application of automated fiber placement/ply handling methods to lean manufacturing, and inability to measure bond integrity.

Approach—Design and fabricate representative components to demonstrate advanced manufacturing technologies and tooling techniques. Investigate manufacturing process simulation models through cure prediction, cure cycle optimization, and structural testing to validate cure cycle optimization and structural efficiency. Demonstrate the use of embedded sensors for adaptive control of the cure cycle through fabrication and test of representative rotorcraft components. Develop and demonstrate the use of nondestructive inspection techniques for determining the integrity of bonded structures.

Challenge—Lack of knowledge about and understanding regarding multidisciplinary design, control of rheological properties during curing, static and fatigue strain limits, fiber marcelling during braiding and weaving, and innovative configurations and concepts tailored to advanced materials applications.

Approach—Develop innovative structural design configurations using advanced materials tailorable for structural efficiency. Develop and demonstrate representative rotorcraft structures using IPPD to optimally meet multidisciplinary design requirements, which include cost, weight, performance, and reliability. Fabricate structural components in sufficient quantities to validate the quality, manufacturing repeatability, structural efficiency, and recurring cost. Develop and demonstrate advanced braiding and weaving equipment and methods to minimize fiber breakage and marcelling. Fabricate structural preforms and incorporate these preforms into tailored structural fittings and components to validate the structural efficiency and recurring costs.

Challenge—Limited displacement capability, limited force capability, limited high cycle fatigue life, and high power requirements of existing smart materials.

Approach—Investigate the force, displacement, and power requirements of new and emerging smart materials for advanced rotor

actuation methods, conduct tradeoff analyses, and demonstrate smart materials applications to rotor actuators through laboratory testing in a dynamic environment.

Challenge—Inability to model and analytically predict the rotating and fixed system structural loads and the interaction of those loads with the vehicles' aerodynamic environment. Inability to conduct detailed stress analyses of complex components under large deformations in a timely manner to support IPPD. Inability to accurately predict crushing loads and behavior of airframe structures in a dynamic crash environment.

Approach—Develop and validate enhanced comprehensive methods that incorporate multidisciplinary technology based on finite element techniques that include composite structures modeling, specifically concentrating on the rotor system loads and aeroelastic stability analysis. Develop and validate reliable finite element analysis modeling and simulation techniques that include large strain effects required to model the energy absorbing characteristics of crushable composite structures.

d. Subsystems

Goals and Timeframes

RWV subsystems encompass a broad range of S&T topics related to the support, sustainment, and survivability of increasingly complex aircraft systems and to the unique problems associated with the application of high performance weapons on rotorcraft. In addition to addressing affordability issues for operation and support (O&S) costs, this area also encompasses the extension of the useful life of weapon systems through upgrading armament and other mission equipment.

The objectives are provided in Table IV–7.

These key technological objectives have been established: reductions in radar cross sections (RCSs) and visual/electro-optical signatures, increased hardening against ballistic and NBC threats, and the autodetection of incipient critical mechanical component failures. Attainment of these objectives will translate into aircraft requiring fewer maintenance hours per flight hour, while still performing safely and effectively in a hostile environment.

Table IV–7. Subsystems Objectives

Subsystems	Improvement (%)		
	By 2000	By 2005	By 2010
Reduction in 0.4–0.7 micron (μm) visual	35	50	60
Reduction in 3–5 μm IR signature	35	50	60
Reduction in 8–12 μm IR signature	35	50	60
Reduction in threat protection weight vs. gross weight	5	10	20
Reduction in total maintenance	15	30	45
Autodetection of critical component	40	60	75

Major Technical Challenges

Challenge—Modeling and analytical predictions for characterization of component materials and integration concepts performance in signature suppression are needed.

Approach—Conduct computer modeling from signature prediction to battlefield simulations. Conduct laboratory and flight testing of cost-effective attenuating materials and design concepts that will reduce IR, RCS, acoustic, visual, and EO emissions from rotorcraft.

Challenge—Modeling and analytical predictions for characterization of component materials and integration concepts performance in hardening are needed.

Approach—Conduct computer modeling of hardening concepts to provide reduced probability of kill across the full spectrum of known threats, as well as crash impacts. Conduct demonstrations of components and of the integration of lightweight armor, directed-energy weapons (DEWs), and nuclear, biological, and chemical

(NBC) hardening that balance cost, weight, and effectiveness.

Challenge—Lack of reliable, rugged, cost-effective, nonintrusive monitoring techniques, sensors, algorithms, and methods.

Approach—Develop a quantified database of the performance of impending component failures. Conduct laboratory and field testing of advanced sensors and monitoring systems.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Air Vehicles is shown in Table IV–8.

5. Linkages to Future Operational Capabilities

The influence of this technology area on TRADOC FOCs is summarized in Table IV–9.

Table IV–8. Technical Objectives for Air Vehicles

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Aeromechanics	Aeroacoustic and aeroelastic prediction codes verified and incorporated in comprehensive analysis Rotor/fuselage interaction CFD-unique experiments High-lift rotor concepts evaluated Low-cost, high-efficiency rotor design methodology initiated CFD/inflow analysis verified	Reduce critical unsteady loads by 50% Reduce vehicle parasite drag by 15% Increase in maximum blade loading by 15% Increase in rotor lift/drag by 8% Increase in rotor figure of merit by 7%	Reduce critical unsteady loads by 70% Reduce vehicle parasite drag by 30% Increase in maximum blade loading by 25% Increase in rotor lift/drag by 15% Increase in rotor figure of merit by 12%
Flight Control	Establish cargo/slung load flight test maneuvers; conduct simulations to develop criteria for hover and low speed Complete terrain correlated turbulence model Develop and transition advanced control law synthesis techniques Complete comprehensive identification from frequency responses (CIFER) UNIX upgrade and train industry Complete IFFC piloted ground simulations Develop techniques for pilot-envelope cueing and limiting	Improve slung load handling qualities to a CHPR of 4 70% increase in bandwidth while maintaining gust rejection capability 60% improvement in weapon-platform pointing accuracy techniques 66% reduction in envelope maneuvering margins	Improve slung load handling qualities to a CHPR of 3 80% increase in bandwidth while maintaining gust rejection capability 80% improvement in weapon-platform pointing accuracy techniques 75% reduction in envelope maneuvering margins

Table IV–8. Technical Objectives for Air Vehicles (continued)

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Structures	Define RWST structured configuration and requirements Select critical components for development, testing, and demonstration in RWST Complete fabrication and testing of resin transfer molding (RTM) trial beam for RAH–66, thermoplastic (TP) horizontal stabilizer for OH–58D, and TP tailboom section for the RAH–66 baseline TP horizontal stabilizer and TP tailboom section for the RAH–66 Develop system architecture for manufacturing and tooling expert system (MATES) and preliminary design concept for damage tolerant hub fixture for RAH–66 baseline Initiate the harmonization of civil and military design requirements, specifications, standards, and the application and refinement of IPPD principle to reduce life-cycle costs	95% accuracy for loads synthesis 30% reduction in recurring production labor hours per pound for composite structures 200% increase in displacement capability of smart materials actuators 98% accuracy with flight regimes recognition algorithms	98% accuracy for loads synthesis 50% reduction in recurring production labor hours per pound for composite structures 400% increase in displacement capability of smart materials actuators 35% increase in structural efficiency
Subsystems	100% probability of detection of impending failures of structural components 20% increased operational durability and repairability of reduced signature materials 15% reduction in infrared and visual electro-optic vehicle signatures 10% increase in ballistic and NBC hardening technique	30% reduction in signatures 25% improvement in ballistic and NBC hardening techniques and concepts 95% probability of detection of impending component failures	35% reduction in signatures 30% improvement in ballistic and NBC hardening techniques and concepts 98% probability of detection of impending component failures

Table IV–9. Air Vehicles Linkages to Future Operational Capabilities

Technology Subarea	Integrated and Branch/Functional Unique Future Operational Capabilities
Aeromechanics	TR 97–022 Mobility—Combat Mounted TR 97–023 Mobility—Combat Dismounted TR 97–029 Sustainment TR 97–037 Combat Vehicle Propulsion TR 97–040 Firepower Lethality TR 97–043 Survivability—Materiel
Flight Control	TR 97–002 Situational Awareness TR 97–016 Information Analysis TR 97–017 Information Display TR 97–022 Mobility—Combat Mounted TR 97–037 Combat Vehicle Propulsion TR 97–040 Firepower Lethality EN 97–001 Develop Digital Terrain Data
Structures	TR 97–022 Mobility—Combat Mounted TR 97–024 Combat Support/Combat Service Support Mobility TR 97–026 Deployability TR 97–029 Sustainment
Subsystems	TR 97–002 Situational Awareness TR 97–022 Mobility—Combat Mounted TR 97–024 Combat Support/Combat Service Support Mobility TR 97–026 Deployability TR 97–029 Sustainment TR 97–035 Power Source and Accessories TR 97–037 Combat Vehicle Propulsion TR 97–040 Firepower Lethality EN 97–001 Develop Digital Terrain Data

E. CHEMICAL AND BIOLOGICAL DEFENSE

1. Scope

The National Defense Act for FY94, Public Law 103–160, consolidated management and funding of both medical and nonmedical chemical and biological defense (CBD) programs under OSD and in separate defense accounting lines. The law designated the Army as executive agent to coordinate and integrate the CBD acquisition program. In that capacity, the Army has elected to present the CBD program in this *Science and Technology Master Plan.* The nonmedical CBD programs are discussed here in Section IV–E, while the medical CBD programs are addressed in Section IV–Q, "Medical and Biomedical Science and Technology."

The CBD program includes those technological efforts that maximize a strong defensive posture in a biological or chemical environment, using passive and active means as deterrents to the use of weapons of mass destruction. These technologies include the areas of chemical and biological (CB) detection, information assessment (including identification, modeling, and intelligence), contamination avoidance, protection of individual soldiers and equipment, and collective protection against weapons of mass destruction.

2. Rationale

Defense against CB agents is accomplished at several levels: enhancing survivability of land combat systems and helicopters, detecting CB agents before personnel are exposed, protecting personnel once agents are employed, decontaminating following exposures, and providing safe and effective medical countermeasures. Related areas include modeling and simulation (M&S) of agent characteristics and modernizing armored systems for CB survivability.

3. Technology Subareas

a. Detection

Goals and Timeframes

Standoff short-range CB detection is being pursued with lasers that can detect, identify, and map chemical vapors, aerosols, and liquids on the ground at ranges of 3–5 kilometers (km). The longer range biological threat will be detected at ranges up to 50 km using eye-safe lasers with enhanced imaging capability that will employ polarization and multiple wavelength excitation to increase discrimination range against natural biological backgrounds (FY00).

Passive technologies such as surface-excited infrared thermoluminescence, being studied for their ability to detect CB agents on the battlefield, require development of atmospheric databases, spectroscopic detection algorithms, and optical telescope designs for airborne and space platforms (FY10). These approaches are being evaluated against the use of multiple point sensors, either distributed throughout the battlespace or mounted on mobile platforms (FY02).

Because of the unique characteristics of CB agents, their physico-chemical properties must be carefully mapped to ensure detection, and a theoretical basis for detecting unknown but related agents must be developed. Infrared, visible, and ultraviolet (UV) spectroscopy, as well as mass, Raman, and laser desorption or electrospray particle trap mass spectrometry (MS), are being applied to this problem. Finally, aerosol science is providing the basis for the development of new optical methods for interrogating aerosol clouds from a distance for the purpose of detection.

Closer to the soldier is point detection. New fluorescent, acoustic, and optical biosensors are being designed for enhanced sensitivity and more flexible detection capability. Recent advances in the acceleration of the polymerase chain reaction (PCR) on a miniaturized scale now permit the exploitation of DNA probes for field detection of pathogens. A major thrust of a *Joint Warfighting Science and Technology Plan* (JWSTP)

Defense Technology Objective (DTO), J.04 "Integrated Detection Advanced Technology Demonstration (ATD)," is the development of a rapid, automated field detection device based on the PCR. One key DTO element is the development of recombinant antibodies to serve as the recognition element of these new biosensors (FY98). Recombinant antibodies will ultimately be designed and quickly selected from genetic "super libraries" (FY99) to have specific detection capabilities, and novel starburst dendrimers are being studied for use on tailored reactive surfaces. Another major approach to point detection is MS, and miniature automated pyrolysis-based versions are being assessed for integration into existing CBD platforms (FY01). Of critical importance for biosensor and MS approaches is bioaerosol sampling, since characteristics (e.g., concentration of detectable units per unit volume of air) of biological aerosols differ dramatically from chemical vapors, with resulting effects on detection efficacy (see Figure IV–1).

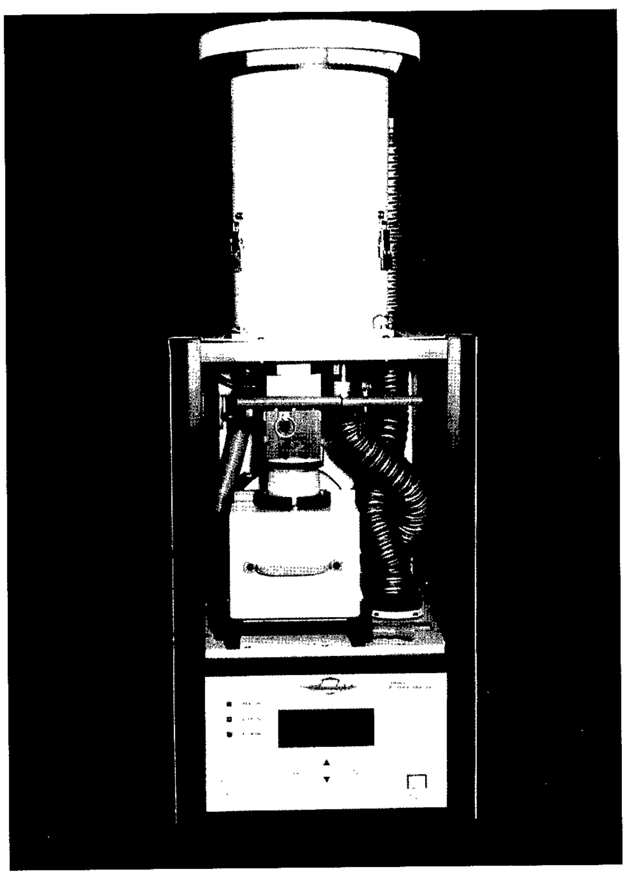


Figure IV–1. Bioaerosol Sampler and Detector

Major Technical Challenges

In the post-World War II era, detection was a simple matter of knowing what agents potential adversaries possessed and designing analytical procedures to detect them. The proliferation of a broad spectrum of biological agents such as toxins, viruses, and bacteria, and the potential for genetically engineered pathogens have complicated this task immeasurably. The ideal detection system would operate continually in a standoff mode and would be capable of detecting all known—and even unknown—agents.

- Detection of biological weapons against a high and variable background of ambient biological material.
- Miniaturization of sensor components using nanofabrication techniques.
- Design and production of biological recognition sites such as genetic probes and recombinant peptides.
- Rapid sampling of aerosols and vapors and modeling of their behavior under different meteorological conditions.

b. Protection

Goals and Timeframes

The second major theme in CBD is protection, and this may be divided into individual and collective protection. The foci of individual protection are to reduce the physiological burden of the protective mask and clothing, thereby reducing performance degradation, to integrate the mask into future soldier systems, and to protect against future CB threat agents. To accomplish these goals, new materials will be needed to decrease breathing resistance (FY05) and increase binocular vision (FY05). Computer-aided design (CAD) and rapid prototyping techniques are being employed to both improve mask performance and manufacturing processes. Supporting this, new physiological and protection tests are being developed. For clothing, selectively permeable and smart membranes are being assessed for enhanced protection and reduced heat stress. Selectively permeable membranes laminated to

lightweight shell fabrics will provide low thermal insulation and high vapor transmission. Incorporation of reactive materials into the membrane will reduce the need for carbon and extend service life. Collective protection S&T efforts focus on advanced filtration and sheltering concepts for assembled troops that promise to reduce the power, weight, and volume of systems as well as to improve protection against NBC threats. Efforts to enhance vapor and aerosol filtration are concentrating on novel materials and processes. Temperature swing adsorption (TSA), pressure swing adsorption (PSA), and catalytic oxidation (CATOX), as well as improvements to existing single-pass filter systems, are under investigation to provide new systems requiring reduced logistical support through greatly increased service life and improved reliability against an evolving CB threat (FY01). Additionally, adsorbent materials with desirable surface characteristics and precisely controlled pore structures are under investigation to identify improvements to the traditional activated carbon substrates (FY10). Investigations are ongoing to assess regenerable fine particle filtration concepts with the potential of providing long-term protection against that class of NBC threats. Also under way are investigations of the integration of regenerative filtration technologies into host weapons systems, the ability to incorporate a surface acoustic wave sensor into a filter bed to signal impending loss of its filtration capacity, and performance of fielded filters against nonstandard threat materials such as industrial vapors. Finally, modeling efforts to describe filter performance based on fundamental properties and process parameters are in progress. Efforts to improve shelter technology are concentrating on novel materials that are more affordable and provide better protection against a broad range of NBC agents.

Major Technical Challenges

The major challenge will be to identify new materials offering improved protection against a broad and evolving spectrum of NBC agents while reducing the physiological burden to the soldier. More specifically:

- Apply new adsorbent technology and materials to improve the performance of TSA and PSA processes as well as the traditional single pass filtration systems.
- Identify new catalytic materials to efficiently destroy chemical agents while minimizing the production of hazardous by-products.
- Develop lighter tent materials with improved protection properties.
- Identify practical regenerative particulate filtration concepts and systems.
- Expand the understanding of integrating standard and regenerable filtration technologies into host systems.
- Develop improved modeling approaches that will permit fast track maturation of new filtration processes.

c. Decontamination

Goals and Timeframes

The third major theme is decontamination, and this can be divided into three categories: immediate—carried out by the individual soldier, operational—carried out by the decontamination unit, and thorough—performed by the chemical company, usually at an equipment decontamination site. Both hydrolytic and oxidative reactions are being studied, with the goal of formulating stable decontaminants with new reactants for rapid destruction of mustard, and V and G nerve agents. Catalytic materials such as enzymes have been cloned and assessed for their ability to destroy chemical agents under mild, ambient conditions, thus avoiding damage to delicate equipment and the environment. An enzyme that degrades G class nerve agents has been scaled up and produced via biomanufacturing, and will be subjected to a NATO field test (FY98). Enzymes that degrade V-class nerve agents are being screened for efficacy and down-selected for scale-up (FY98). Ultimately, these new catalytic materials may be incorporated into sorbents and self-decontaminating coatings, fibers, or paints (FY10) (see Figure IV–2).

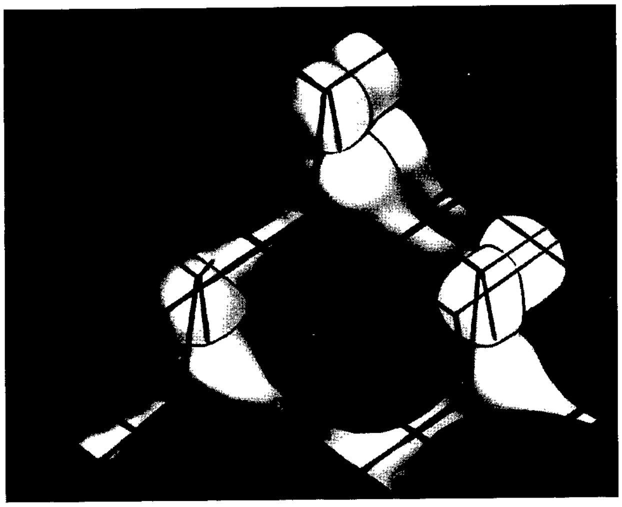


Figure IV–2. Molecular Model of Catalytic Oxidation

Major Technical Challenges

The main technical objective is to design decontaminating materials with highly catalytic properties, long shelf life, and an ability to function under a broad range of temperatures and pH.

- Using molecular modeling and site-directed mutagenesis, design catalytic enzymes with enhanced turnover (i.e., degradative) rates, and stability under various environmental conditions.
- Design and synthesize conductive polymers and finishes that incorporate catalytic enzymes or their active sites.

d. Modeling and Simulation

Goals and Timeframes

The use of M&S is an essential aspect of the current and future CBD program. Advanced computer simulation technology will allow soldiers to be immersed in a realistic and physically accurate computer-generated combat environment that includes CB agent cloud movement and target effects under variable weather, terrain, and foliage conditions. This capability will allow the military user, for the first time, to experience the impact and consequences of CB weapons of mass destruction (WMD) in operational situations and, more important, will demonstrate the potential value of CBD equipment (FY01). Simulations of both conceptual and actual CBD equipment will result in improved and stable performance requirements to be established early in development (FY01). The distributed interactive simulation (DIS) network will enable the user to evaluate the "value-added" of each CBD item at every phase of development (see Figure IV–3). By means of virtual prototyping, soldiers will contribute to the detailed design of new equipment throughout the development cycle. The combination of constructive (wargaming) and virtual (3D) simulations will permit CBD hardware performance characteristics to be optimized prior to production. Virtual prototyping will greatly decrease the acquisition time and associated costs of development, including test and evaluation (T&E) elements. The mutual interaction between user and developer, provided by M&S throughout the acquisition cycle, will result in superior CBD products within the limited funding and resource constraints anticipated for the future.

As the threat evolves and proliferates, it becomes increasingly important to be able to identify, synthesize, and assess the physicochemical and toxicological properties of new compounds. These studies are being used to develop quantitative structure-activity-property relationships and, ultimately, to predict the behavior of new compounds in biosystems. Novel, short-acting sedatives are being developed from these efforts as potential less-than-lethal chemicals for a variety of applications, and candidate nontoxic simulants with reduced environmental impact are also being selected and tested.

Major Technical Challenges

The two main objectives for M&S are to develop models that accurately predict the effect of chemical and biological warfare (CBW) agents on battlefield performance, as well as the protective capability of CBW defense equipment. Second, to model structure-activity relationships to

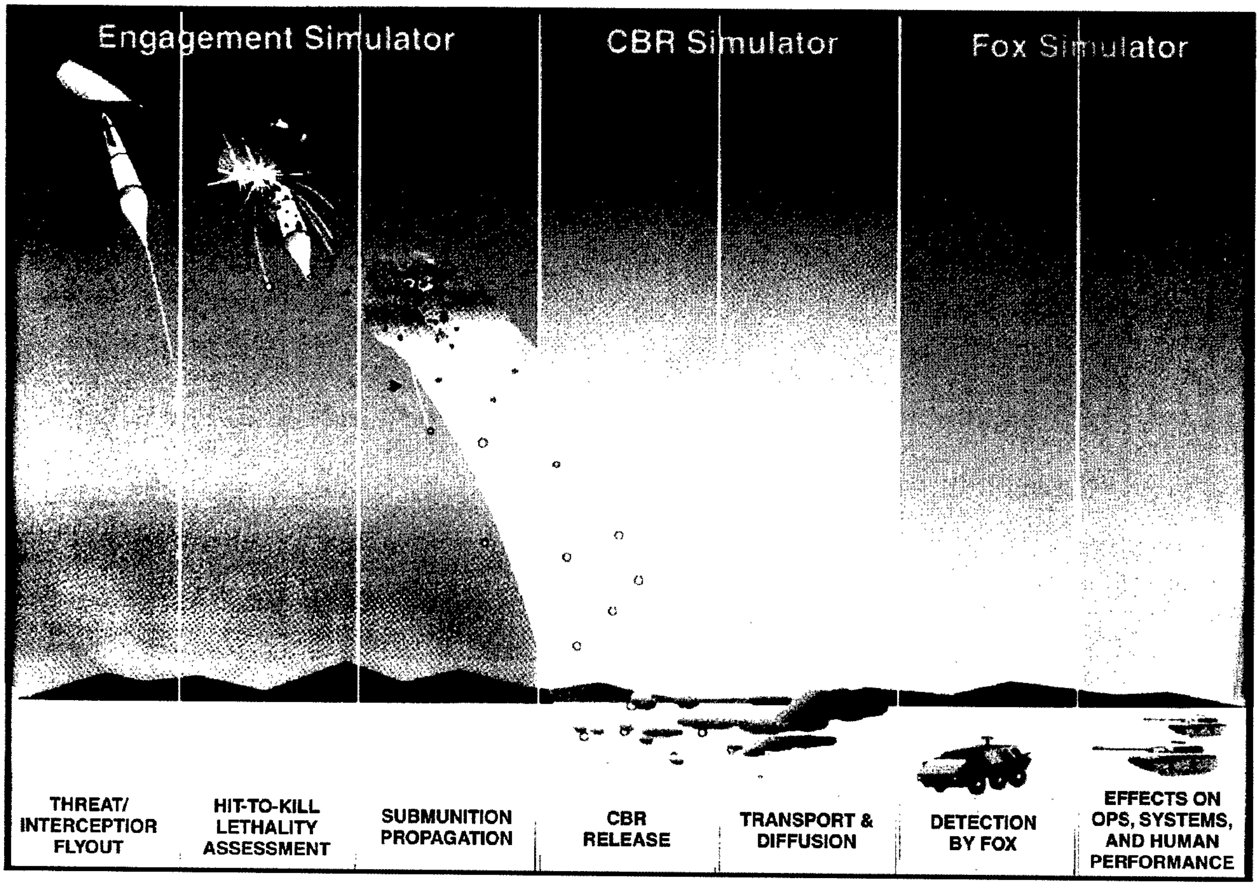


Figure IV–3. Simulation of Intercept of Chemical or Biological Agent Munition

predict the threat potential of new compounds and their behavior in both bio- and ecosystems.

- Develop a verifiable capability to analyze CB detectors and detection systems in existing "constructive" wargames.
- Formulate a "value-added" methodology using DIS to assess the operational benefits of CB defensive equipment in the light-to-moderate battlefield situations.
- Enhance the display and assessment ability for tactical ballistic missile interception of CB warheads within the "virtual environment" simulation arena.
- Create a verifiable methodology using the "VL STRACK" cloud transport and diffusion model to depict the movement of military vehicles through/around diffusing CB clouds, and through and around heavy foliage and wooded terrain.
- Install modules addressing CBD functions (detection, protection, decontamination, and survivability) into joint service computer wargames to enhance comparative decision making earlier in the acquisition cycle.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Chemical and Biological Defense is shown in Table IV–10.

5. Linkages to Future Operational Capabilities

The influence of this technology area on TRADOC FOCs is summarized in Table IV–11.

Table IV–10. Technical Objectives for Chemical and Biological Defense

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Detection	Genetically engineered antibodies Flow cytometry as an immunoassay platform for biodetection	Genetic super library Early warning of bioagent detection at 1–5 km Automated single step point detection Subsymptomatic chemical agent interior monitor Early warning of aerosol cloud at 5–50 km Small, lightweight chemical monitor	Lightweight CB detection from unmanned ground vehicle (UGV)/unmanned aerial vehicle (UAV) platform Miniaturized photo-array detection/identification of biological agents Standoff chemical detection at 20 km CB water and surface contamination monitor Man-portable integrated CB detection system
Individual Protection	24-hour liquid protection 50% reduction in breathing resistance Develop advanced selectively permeable membrane eliminating/reducing the use of carbon in chemical protective ensembles	50% increase in binocular vision Expanded performance degradation model Compatibility with future soldier systems	Full field of view (FOV) through transparent face piece New super dense absorbents Smart barrier membranes
Collective Protection	Prototype pressure swing absorption (PSA) system Laboratory scale temperature swing absorption (TSA) system	Combined PSA/TSA/CATOX system Engineered absorbents	Monolithic filtration media Membrane filtration
Decontamination	New polymers with agent reactive sites for more efficient decontamination (decon)	Automatic decon through conductive coatings	Self-decon coatings
Modeling and Simulation	Distributed interactive simulation capability for CB detectors	Upgraded wargames and virtual prototypes of CBD equipment	Virtual reality using man in the loop Virtual/actual CBD equipment in fully integrated constructive and virtual combat simulations

Table IV–11. Chemical and Biological Defense Linkages to Future Operational Capabilities

Technology Subarea	Integrated and Branch/Functional Unique Future Operational Capabilities
Detection	TR 97–020 Information Collection, Dissemination, and Analysis TR 97–022 Mobility—Combat Mounted TR 97–030 Sustainment Maintenance TR 97–043 Survivability—Materiel
Individual Protection	TR 97–030 Sustainment Maintenance TR 97–038 Casualty Care, Patient Treatment, and Area Support TR 97–044 Survivability—Personnel
Collective Protection	TR 97–030 Sustainment Maintenance TR 97–038 Casualty Care, Patient Treatment, and Area Support TR 97–044 Survivability—Personnel
Decontamination	TR 97–030 Sustainment Maintenance TR 97–038 Casualty Care, Patient Treatment, and Area Support
Modeling and Simulation	TR 97–002 Situational Awareness TR 97–052 Training Aids, Devices, Simulators, and Simulations Fidelity Requirements TR 97–054 Virtual Reality TR 97–057 Modeling and Simulation

F. INDIVIDUAL SURVIVABILITY AND SUSTAINABILITY

The subareas of individual survivability and sustainability (ISS) are an integral part of the human systems area. ISS corresponds to the warrior protection and sustainment subarea of the human systems technology DTAP.

1. Scope

ISS focuses on protecting and sustaining the individual warfighter—ultimately the most critical element of any weapon system on the digitized battlefield. By providing food, drinking water, clothing, airdrop, and shelter, this technology area ensures warfighter survivability and performance and enhances readiness and quality of life on the battlefield and in operations other than war (OOTW).

This technology area comprises two subareas: individual survivability and sustainability. The individual survivability subarea includes all material and combat clothing systems for protection of the individual warfighter. These efforts provide technological advancements in individual ballistic protection, countermeasures to sensors, laser eye protection, multifunctional materials, and warrior performance and endurance enhancements, as well as integration of capability enhancing technologies (e.g., individual combat identification, system voice control, rapid target acquisition, self-contained navigation and display, unexposed firing/viewing) with the protective clothing/load-bearing system.

The sustainability subarea includes scientific and technological efforts to sustain and enhance warfighter performance and combat effectiveness. These range from nutritional performance enhancement, food preservation, food service equipment, energy technologies, and drinking water to advanced and precision cargo/personnel airdrop and airbeam technologies for shelters. Technologies pursued in this effort address the need to "fuel the fighter"—to deliver the right nutrients at the right levels at the right time in the right combination, to provide versatile airdrop capabilities critical to worldwide force projection and resupply, and to provide rapidly deployable food service equipment and shelters in forward areas.

2. Rationale for Investment

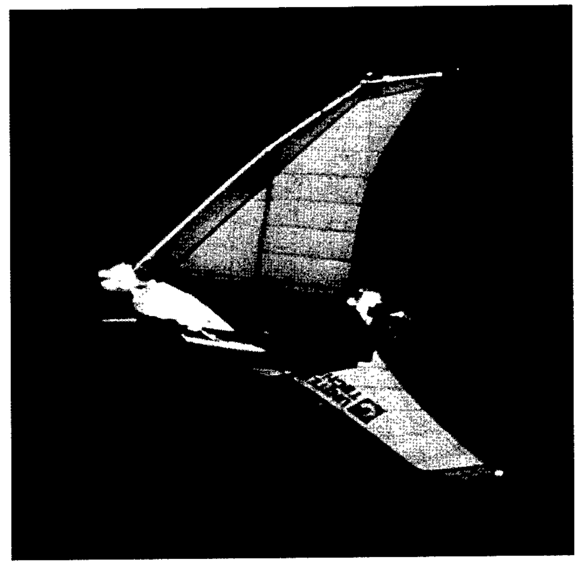
a. Relationship to Military Capabilities/Needs

Success on the battlefield relies heavily on continuous availability of warfighters and on optimizing their performance. Keys to accomplishing this are to mitigate personnel risk and to enhance the capabilities of individual warfighters in an operating environment. ISS technologies enable warfighters to perform their missions and survive in normal and emergency operational environments. (Refer to individual subareas for more specific relationships to military capabilities.) Figure IV–4 depicts the four Army mission requirements supported by these subareas: integrated protective clothing and equipment, rations and water, air delivery systems, and airbeam-supported shelters.

b. Technical Forecast

Numerous foreseeable advances in individual survivability technologies exist. They include development of next-generation advanced materials for multiple threats, including flame protection, technology to provide fragmentation and small arms ballistic protection at 20 to 30 percent reduced weight, and materials to prevent detection by multispectral sensor devices. Clothing systems that provide thermal and environmental protection with minimum bulk and weight are also on the horizon. Another priority is integrating capability-enhancing technologies into the various soldier systems, such as Land Warrior, Mounted Warrior, and Air Warrior for unique operational environments (e.g., Military Operations in Urban Terrain (MOUT)). Integrated soldier and small unit battlefield performance simulations that support analysis of technology enhancements are also being developed and applied.

Integrated Protective Clothing and Equipment: Land Warrior outfitted for the 21st century with a computer/radio, protective clothing, and individual equipment, software, integrated helmet assembly, and weapon systems.



Air Delivery Systems: High-Glide, Semirigid Wing Air Delivery System, a high-altitude autonomously guided, offset cargo airdrop system that will minimize aircraft vulnerability to low-altitude threats and enhance the rapid deployment and precision delivery of sensors and munitions.

Rations and Water: Nutritious field rations and water fuel the combat soldier and enhance performance.

Airbeam-Supported Shelters: Airbeams will drastically reduce weight, setup time, and packed volume of current frame-supported tents. (Large area night maintenance shelter shown.)

Figure IV–4. Army Mission Requirements in Individual Survivability and Sustainability

Foreseeable advances in sustainability technologies include targeted and modulated nutrient delivery for heightened mental acuity and physical performance, use of intrinsic chemical markers to validate sterility of thermally processed foods, and biosensors to monitor ration deterioration. Also being explored are the use of nonthermal processing technologies (such as irradiation or pulse electric fields) to preserve foods, self-heating operational rations, and a 200 percent increase in kitchen fuel efficiency and power density obtained by converting kitchens to thermal fluid heat transfer. A diesel reforming technology could provide a versatile new fuel for kitchens and soldiers' individual equipment, while a non-electric and thermal storage technology could facilitate self-contained mobile refrigeration systems. In addition, cogeneration systems that provide heat and electric power for field kitchens at nearly 100 percent of the heat value of the fuel and a new water purification technology are being created. Also coming are prediction of parachute behavior and performance during parachute opening, autonomous and precise guidance, navigation, and control for standoff air delivery using flexible gliding wings, parachute design for manufacturability, soft landing technologies, and new textile manufacturing technology for airbeams for field shelters.

c. Payoffs

Improved and integrated individual survivability capabilities, including improved ballistic protection, enhanced load-bearing, countermeasures to sensors, flame resistance, and laser eye protection will permit the Army to engage regional forces promptly in decisive combat while protecting the force. Many technologies will reduce casualties, increase mission duration, and speed turnaround time, which ultimately reduce manpower costs and save lives. Although soldier systems may be more costly on an individual basis, the systems will be more lethal and the individual more survivable. Ultimately, it will be more cost effective by permitting a smaller standing Army. Integration efforts will lead to revolutionary breakthroughs by providing the soldier, as a weapons system platform, more effective, efficient, and precise/accurate means of fighting.

In the sustainability area, payoffs include ration systems that sustain and support highly mobile, forward-deployed troops and provide enhanced performance capabilities such as improved target acquisition, enhanced cognitive skills and decision making (particularly under stressful battlefield conditions), extended mission endurance, and increased alertness. Improved food packaging protects and prevents ration components from physically or microbiologically deteriorating in extreme conditions. Other improvements are enhanced food safety/stability and quality in all environments, fuel/energy efficiency, full use of resources, technology to provide drinking water, and operational readiness and rapid deployability.

Specific payoffs in airdrop technology include the means of delivering critical equipment, personnel, and supplies with greater accuracy, safety, and precision, resulting in greatly reduced personnel airdrop injury rates and increased survivability of delivery aircraft. Also, reducing drop zone size requirements in supporting rapid force entry tactics can result in a faster consolidation of force and allow for just-in-time resupply of rapidly moving forces. Reduced development, testing, and procurement costs will result from predictive performance and design optimization modeling and virtual testing. Pressurized airbeam technology will provide significant reductions in weight, set-up times, and packed volume of soft shelters for rapid deployability in forward areas.

d. Transition Efforts

Emphasis is placed on moving cutting edge technologies into engineering and manufacturing development (EMD) programs through ATDs and technology insertions.

The Soldier Enhancement Program (SEP) is another effective means of getting new technology to the field quickly. There is extensive collab-

oration with industry as evidenced by current active Cooperative Research and Development Agreements (CRDAs). Although some investment is focused on military-unique applications, many of the basic clothing, food, and portable shelter technologies are inherently dual use. (Refer to the individual subareas for more specific transitions and dual-use opportunities.)

3. Technology Subareas

a. Individual Survivability

Scope

The individual survivability technology subarea addresses the full range of combat, environmental, and special purpose protective materials and components. The program includes textile and composite-based material systems and design concepts for individual ballistic protection, countermeasures to sensors, multifunctional materials (including environmental and flame/thermal protection), warrior performance and endurance enhancement, laser eye protection, smart textile materials, and integration of soldier system modular components. Supporting technologies include bioengineered materials for protection and analytic tools with resolution to capture battlefield effects of fatigue, load, environmental exposure, hydration, and terrain.

Potential Payoffs

Impact on Military Capability

Individual survivability technology development and integration efforts provide the fundamental protection and operational capability enhancements that maximize the Army's most precious resource—the soldier. By protecting the soldier in combat and OOTW, this area supports the *Joint Vision 2010* operational concept of full dimensional protection. Protective systems will provide major and direct benefit to the future DoD/Army mission to enable full spectrum dominance. Enhanced protective systems are critical to the survivability, lethality, and mobility of the warfighter. The weight of protective clothing and equipment is approximately 40 pounds, or 46 percent of the total weight of the Soldier system as presently configured. This area will make significant reductions in the weight of the equipment the individual warrior will have to carry/wear. The potential now exists for revolutionary achievements through the emerging field of smart materials. Development of smart materials may be the answer to the explosive pace of technology advancements in sensors, electronics, and information technology.

Potential Benefits to the Industrial Base

Dual-use applications include high-performance fibers for ballistic/blast protection for law enforcement agencies, aircraft cargo containers, use in aerospace, electronics, and automobile industries, and recreational sport applications. Flame and thermal resistant fibers have strong dual uses in firefighting applications, race car driving, industrial workwear, hotel furnishings, children's sleepwear, and piloting. The anthropometric database/models have commercial applications in the design and sizing of clothing systems and equipment such as boots, athletic footwear, gloves, and helmets. CRDAs with industry and development programs with major universities are aggressively pursued. Seven active CRDAs include biogenetically engineered spider silk (Hoechst-Celanese, Inc.), enzymatic synthesis of new polymers (Rohm and Haas), processing and spinning silk (Agricola), protective films from milk fat (National Dairy Board), environmental protective clothing and equipment (L. L. Bean), environmental protective technology (W. L. Gore), and body armor (Massachusetts State Police).

Technology Development Plan

Survivability Technology Taxonomy

- *Ballistic Protection*—Research for protection against flechettes, small arms, and high velocity fragmentation and blast threats from mines and bursting munitions. DARPA is contributing to the development of ultra-lightweight-armor technologies.

- *Countermeasures to Sensors*—Research on textile materials for camouflage for the individual soldier.
- *Multifunctional Materials*—Fibers, fabrics, clothing systems, and techniques for individual protection in all climates against high heat sources and flame, and across all terrains and environmental extremes, including encapsulation and water immersion, whole body protection against lasers, microwaves, and nuclear/thermal threats, and smart materials to enhance integration capabilities.
- *Warrior Performance and Endurance Enhancement*—Research and integrated application of anthropometry, biomechanics, and biophysics as scientific/engineering tools. Integrated individual protective systems and mechanisms to reduce effects of physical and environmental stresses, increase mobility and mission duration, and optimize the human/material/equipment interface.
- *Laser Eye Protection*—Research into technologies affording protection from multiline and tunable lasers.
- *Systems Integration*—Applying systems and concurrent engineering principles to discrete Soldier system technologies, components or processes in order to optimize performance and capabilities and to maximize return on investment.

Major Technical Challenges/Approaches

Challenge—Develop armor material system for protection against combined fragmentation and small arms threats at a 20–30 percent reduced areal density over current small arms protection without a significant increase in other penalties.

Approach—Conduct analyses of fiber properties, textile structure, and/or textile architecture to enhance performance, e.g., investigate functionally graded design/hybridization, determine appropriate configurations for advanced materials, investigate improved textile structure through low-cost weaving technology and thermoplastic resin systems, and develop/evaluate promising alternate material concepts for small arms protection.

Challenge—Provide passive protection against advanced sensors without degrading current visual and near-IR camouflage protection, while maintaining desired/required textile properties (e.g., durable, launderable, flexible, nontoxic). Countermeasures should not increase the bulk or heat stress on the soldier beyond levels imposed by existing clothing systems.

Approach—The sensor of major importance at present is the thermal imager. Based on physics, there are two approaches to solving this problem for the soldier: control the emissivity of the uniform or cool the soldier so that he provides a less conspicuous target to the sensor. Since a passive (not powered), lightweight system is desired, research has concentrated on novel materials to control the emissivity without degrading fabric protection.

Challenge—Durable combat uniforms that provide protection against multiple threats, that are cost-effective, and that do not impose a heat stress penalty.

Approach—Define minimum levels of flame protection required in clothing systems and develop appropriate performance test methods for flame protective materials so that requirements can be verified and developed. Explore novel fibers, fiber blends, fabric constructions, and functional finishes that will provide protection against flame, environmental, and electrostatic hazards while providing visual and near-IR (NIR) camouflage protection.

Challenge—Provide eye protection against lasers capable of causing retina damage (lasers that emit visible or near-IR light).

Approach—Investigate the fundamental physics underlying the phenomena and develop a means to incorporate the most promising nonlinear optical (NLO) materials into an effective and useful configuration for eye protection.

Challenge—Modular performance-augmenting components integrated within the fighting systems.

Approach—Using biomechanical and mechanical engineering tools, develop an ergonomically efficient load-bearing system that is compatible with other system components, is comfortable, reduces fatigue and localized injury, and increases mobility and combat effectiveness. Develop a boot design to reduce stress-related lower extremity injuries and enhance locomotor efficiency.

Challenge—Reduce the weight penalties associated with electronic cables used by various soldier systems, such as MOUT, Land Warrior, Mounted Warrior, and Air Warrior.

Approach—Investigate conductive polymers / materials and develop novel ways to incorporate them into combat uniform fabrics and / or protective uniform systems.

b. Sustainability

Scope

This subarea focuses on warfighter sustainment by providing high-quality, nutritious rations, drinking water, advanced airdrop capabilities, and rapidly deployable food service equipment and inflatable shelters for forward areas. In the ration area, efforts focus on the unique military combat field feeding requirements not addressed in the private sector: low volume and weight, modularity, high nutrient density, storage stability under environmental extremes, efficient use of battlefields fuels for equipment, and the battlefield logistics of providing hot food. S&T efforts include three main areas:

- Nutritional performance enhancement by formulating rations to provide energy and essential nutrients, and to increase alertness and extend endurance in combat and in environmental extremes.
- Ration preservation and stabilization to prevent microbial, physical, and biochemical deterioration and to withstand the rigors of long-term military storage and distribution worldwide.
- Field food service equipment and systems that are highly mobile, fuel efficient, and consistent with minimizing the logistics burden.

Innovative water purification technology is being developed to provide drinking water to field troops. In the airdrop areas, efforts focus on advanced and precision offset air delivery for cargo, personnel, and sensors / submunitions, high glide deployable wings, the integration of guidance, navigation, and control for rapid deployment and just-in-time resupply, and soft landing technologies for cargo and personnel. Inflatable airbeam structure technology, including 3D weaving and braiding, and scaling and shape definition will provide airbeam shelters for rapidly deployable forces and continuous operations of tactical rotary aircraft and combat vehicles.

Potential Payoffs

Impact on Military Capability

In the sustainability area, performance-enhancing ration components will increase the warfighter's mental acuity, physical performance, and ability to deal with battlefield stress. New thermal and nonthermal preservation and active packaging technologies will result in the capability to provide high quality rations for optimizing nutrient consumption. Ongoing and planned innovations in combustion, heat transfer, cogeneration, and refrigeration will enable a new generation of rapidly deployable kitchens that will deliver higher quality meals faster and cheaper, and that will be able to operate in more tactical and climatic environments to ensure that all warfighters can receive at least one hot cooked prepared meal per day.

A new water purification technology will be applicable to military water treatment equipment ranging from individual purifiers to division and

corps level units. This new technology will meet or exceed the performance of existing reverse osmosis membranes.

Initiatives in advanced and precision airdrop technology will provide capabilities critical to both rapid worldwide insertion of continental United States (CONUS)-based initial forces and just-in-time resupply of rapidly moving forces. Airdrop technology also provides a low-cost, highly accurate means of delivering personnel, munitions, and batteries and of emplacing sensors necessary for real-time knowledge and digitization of the battlefield, and for precision-guided, standoff delivery to reduce the vulnerability of the delivery aircraft and crew.

Inflatable airbeam structures provide rapidly deployable shelters in forward areas for performing vehicle and aircraft maintenance in adverse environments and under blackout conditions. Also, these inflatable structures will assist in quickly establishing a presence in remote areas without adequate facilities for maintenance, storage, medical, billeting, and command and control (C^2) centers.

Potential Benefits to the Industrial Base

Significant dual-use applications exist for disaster and humanitarian relief, for sports and other recreational activities (campers, backpackers, hunters, etc.), for forest firefighting, and for special dietary concerns (shelf-stable flexibly packaged foods). Development of a new nonhazardous chemical ration heater while improving the safety of military packaged rations will also be integrated into a line of commercial self-heated meals that will be marketed for commuters, school lunches, and field occupations. Diesel reforming technology has application for residential and industrial heating. Cogeneration technology has application for emergency power and backup for power failures. Refrigeration technology has application for remote sites and humanitarian missions such as transporting vaccines and medical supplies. The new water purification technology will also be applicable to municipal desalination plants.

CRDAs include meals in microwave retort pouch (My Own Meals, Inc.), radiation preservation of foods (Food Technology Service, Inc.), shelf stable breads and bakery products (Mila's European Bakery), shelf stable bakery products (Sara Lee), microencapsulation of performance modifying nutrients (BioMolecular Products, Inc.), edible films (Marine Polymer Technologies, Inc.), encapsulation systems for lipids and flavors in military rations (IGI, Inc.), individual ration components for military/commercial use (M&M, Mars, Inc.), integration of hydrogen suppression material in flameless ration heater (Zestotherm, Inc., and Dynatron, Inc.), intermediate moisture foods (Good Mark Foods, Inc.), antifungal/antibacterial agent (CAREX, Inc.), and airbags as impact attenuators for airdrop soft landing (Marotta Scientific Control, Inc.). Several additional CRDAs are under negotiation.

While industry has assumed the lead role in applying irradiation technology, supported research in coordination with United States Department of Agriculture (USDA) and industry contributes directly to providing the scientific basis required for gaining regulatory approval for the use of this technology for both military and civilian benefit. Additionally, there is joint industrial collaborative research to exploit novel quality enhancement and quantification technologies, high pressure processing treatment, and ohmic processing. Using novel methodologies developed by the Department of the Army, these new processes will be validated as microbiologically safe and will lead to the production for both civilian and military consumers of a wide variety of safe and appealing foods that would not be possible using conventional thermoprocessing.

Technology Development Plan

Specific sustainability technology efforts are defined by the following taxonomy:

- *Preservation and performance enhancing technologies*—Research in food science (e.g., encapsulation, molecular inclusion), physical chemistry, behavioral sciences, chemical engineering, and packaging, as they relate to novel food

formulation, nutrition, nutritional biochemistry, neurophysiology, preservation, stabilization, processing, protection, and other related technologies.

- *Food service equipment/energy technologies*—Research in combustion, thermodynamics, heat transfer, cogeneration of electric power and heat, automatic control, material, and refrigeration technologies.
- *Water purification technology for drinking water*—Research to prove the feasibility of a technology with a 300 percent increase in operating/storage life, a 50 percent increase in water flux, and tolerance of 5-parts per million (ppm) chlorine when compared with conventional reverse osmosis.
- *Airdrop technology*—Research in designs and concepts for parachutes/gliding wings and cargo/personnel airdrop systems; aerodynamics and guidance, navigation and control of deceleration; theoretical/computational prediction and experimental determination of decelerator behavior and performance; and personnel/system interfaces to improve safety and logistics.
- *Airbeam technology for shelters*—Research in fibers, fabrics, fabric stress/strain properties, manufacturing technologies, coatings and concepts for airbeam structures and textile-based shelters.

Major Technical Challenges/Approaches

Challenge—The natural complexity of food systems affects the chemical, physical, and nutritional characteristics and leads to undesirable changes that are often further compounded by lengthy, uncontrolled storage.

Approach—Determine relationship between formulations/processes and glass transition temperature using dynamic mechanical analysis and electron spin resonance, and correlate results with rate of change of critical physical and chemical properties of rations. Evaluate new preservation methods that produce shelf-stable foods with the taste and appearance of "home-cooked" meals. Investigate multifunctional packaging adjuvants (e.g., oxygen scavenging, antimicrobial, nutrient protection, color protection).

Challenge—Methodology to provide data needed to establish links between specific nutrient intake and performance.

Approach—Investigate methodologies for assessing the bioavailability and uptake of a variety of nutrients. Develop rapid and precise methods for determining physiological availability of nutrients in rations subjected to time-temperature stresses.

Challenge—Improve field-feeding capability by increasing fuel efficiency from the current 15–20 percent to 80 percent, improve kitchen habitability, meal output and quality, deployability, reliability, and ability to transport and store perishable items.

Approach—Develop diesel fuel reforming, thermal fluid heat transfer, cogeneration, and thermal storage and stabilization technology and integrate these developments into field kitchens.

Challenge—Develop new water purification technology with a 300 percent increase in operating and storage life, a 50 percent increase in water flux, tolerance to 5 ppm chlorine, temperatures up to 165°Fahrenheit (F), and pH from 5.0 to 9.5 when compared to conventional reverse osmosis membranes.

Approach—Explore new desalting technologies that are lighter, more economical and energy efficient than current systems. Technologies currently being investigated are polymeric microgels, which remove specific contaminants; mosaic membranes, which may increase water production while having chlorine resistant properties; and polyphosphazene membranes, which will incorporate biofouling resistance.

Challenge—Analysis of the transient parachute opening processes, including the complicated interaction between the flexible and porous

parachute canopy fabric and its surrounding air flow.

Approach—Numerical coupling of the air flow process and the canopy fabric requires unsteady 3D fluid / structure analysis and modeling.

Challenge—Effectively dissipate airdrop kinetic energy to provide a soft-landing capability for cargo and personnel.

Approach—Investigate and demonstrate airbags with advanced gas injection technologies for application to heavy cargo airdrop. Conduct predictive performance modeling, experimentation, and demonstration of gas operated parachute retraction concepts for application to light cargo and personnel airdrop. Explore new decelerator concepts that provide increased drag efficiency.

Challenge—Lower cost, lighter weight, reduced volume parachutes.

Approach—Develop and demonstrate advanced hybrid architecture for personnel and cargo parachute applications that optimize performance with minimal construction, using 2D woven fabrics. Investigate and exploit 3D weaving technologies that virtually eliminate joints and seams in constructed parachutes.

Challenge—Producible, reliable airbeam fabrication.

Approach—Small diameter, high pressure airbeams will be demonstrated by continuously braiding and weaving a high strength, 3D fabric sleeve over an air retention bladder. Scaling parameters and airbeam structural behavior will enable fabrication for various sizes of soft shelters.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Individual Survivability and Sustainability is shown in Table IV–12.

Table IV–12. Technical Objectives for Individual Survivability and Sustainability

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Individual Survivability	Demonstrate an improved system for protection against combined fragmentation and small arms threats, to be measured by a 20 to 30% reduction in areal density (weight per given area) Develop whole body scan protocols compatible with anthropometric survey (ANSUR) 2D database standards Provide modeling, simulation, and analytical tools to reduce risk of Force XXI Land Warrior program Demonstrate silk-based fabric for ballistic protective applications Demonstrate prototype boot that reduces stress-related lower extremity injuries Demonstrate an effective, lightweight nonpower electrochemical microclimate cooling system Optimize thermal signature reducing face paints	Transfer materials technology for individual countermine protective system to provide equal protection at a 35% reduction in system weight Demonstrate a tunable laser eye-protective device incorporating NLO materials Develop fully integrated soldier system analytical model Demonstrate a novel multifunctional fabric system with a 50% decrease in the cost of flame protection Integrate technology upgrades to the Land Warrior system Demonstrate combat uniform systems that reduce the soldier's signature by 50% Develop conductive fibers/ materials for combat clothing	Demonstrate novel, highly oriented organic fibers for ballistic protective clothing materials Develop next generation advanced camouflage combat uniforms Develop reactive and catalytic protective clothing materials, uniform system designs, and production capabilities for global rapid response and diverse missions

Table IV–12. Technical Objectives for Individual Survivability and Sustainability (continued)

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Sustainability	Identify and optimize the incorporation of complex carbohydrates for modulated energy release during period of high demand Develop a diesel fuel reforming capability for producing a natural-gas-like fuel for field kitchens Demonstrate wide span inflatable airbeam technology for the Aviation Maintenance Shelter Fabricate a high glide airdrop system that has a 2,000–5,000-pound payload capacity Develop glass-coating technology for flexible or semirigid retortable nonfoil packaging materials to extend shelf life Develop in-package additives to prevent oxidation and other forms of product degradation Demonstrate a parachute retraction system using clustered parachutes that provide a less than 10 feet/second soft landing capability Utilizing advanced airfoil and parachute designs, demonstrate a gliding personnel parachute with a 20% increase in maximum jump altitude and a 25% increase in glide ratio, compared to the current Army state-of-the-art MC–4 parachute Demonstrate an innovative purification technology that will provide drinking water for troops in the field Demonstrate a high-glide airdrop system that can carry a 2000- to 5000-lb payload using an advanced guidance package and a high-glide wing	Develop shelf-stable solid muscle foods providing A-ration-like quality using irradiation Select/incorporate neurotransmitter precursors in ration components/supplements for anti-stress benefits Demonstrate a rapidly deployable field kitchen featuring advances in diesel combustion, heat transfer, integral power, and refrigeration that can produce high quality meals quickly and economically Validate nonthermal preservation techniques used to minimize nutritive losses Demonstrate interactive packaging technology (e.g., emitters/absorbers) for shelf-stable and perishable food production applications Transition the 2000– to 5000–lb payload capacity high-glide airdrop Demonstrate less than 10 G (gravitational force) soft landing airbag system that provides an all weather, rapid roll-on/roll-off airdrop capability for future Army Using novel design techniques, demonstrate a cargo size parachute with a 20% reduction in weight bulk and manufacturing cost (compared to fielded parachutes) while providing equivalent flight performance Demonstrate a soft land capability that augments personnel parachute performance and will reduce system descent rates to values below 16 feet/second, using "pneumatic muscle" technologies	Achieve optimized calorie/nutrient consumption Target nutrient delivery systems to ensure maximum bioavailability of key nutrients Demonstrate a totally integrated self-contained field feeding system based on advances in food, packaging, shelter, and energy technologies Investigate powered gliding wing airdrop systems Demonstrate advanced airdrop recovery/stabilization technologies that reduce ground dispersion and personnel/equipment link-up times Demonstrate advanced airdrop performance simulation technologies, as virtual test proving ground enablers, that reduce test cycle time/cost

5. Linkages to Future Operational Capabilities

The influence of this technology area on TRADOC FOCs is summarized in Table IV–13.

Table IV–13. Individual Survivability and Sustainability Linkages to Future Operational Capabilities

Technology Subarea	Integrated and Branch/Functional Unique Future Operational Capabilities
Individual Survivability	TR 97–022 Mobility—Combat Mounted TR 97–023 Mobility—Combat Dismounted TR 97–027 Navigation TR 97–044 Survivability—Personnel TR 97–045 Camouflage, Concealment, and Deception TR 97–048 Performance Support Systems
Sustainability	TR 97–001 Command and Control TR 97–002 Situational Awareness TR 97–003 Mission Planning and Rehearsal TR 97–004 Tactical Operation Center Command Post TR 97–006 Combat Identification TR 97–007 Battlefield Information Passage TR 97–008 Power Projection and Sustaining Base Operations TR 97–009 Communications Transport Systems TR 97–010 Tactical Communications TR 97–011 Information Services TR 97–012 Information Systems TR 97–015 Common Terrain Portrayal TR 97–019 Command and Control Warfare TR 97–020 Information Collection, Dissemination, and Analysis TR 97–022 Mobility—Combat Mounted TR 97–023 Mobility—Combat Dismounted TR 97–024 Combat Support/Combat Service Support Mobility TR 97–025 Countermobility TR 97–026 Deployability TR 97–027 Navigation TR 97–028 Unmanned Terrain Domination TR 97–029 Sustainment TR 97–030 Sustainment Maintenance TR 97–031 Sustainment Services TR 97–032 Sustainment Logistics Support TR 97–033 Sustainment Transportation TR 97–034 Enemy Prisoner of War/Civilian Internee Operations TR 97–035 Power Source and Accessories TR 97–038 Casualty Care, Patient Treatment, and Area Support TR 97–039 Lines of Communications Maintenance and Repair TR 97–040 Firepower Lethality TR 97–042 Firepower Nonlethal TR 97–043 Survivability—Materiel TR 97–044 Survivability—Personnel TR 97–045 Camouflage, Concealment and Deception TR 97–046 Battlefield Obscuration TR 97–048 Performance Support Systems CSS 97–002 Containerization and Packaging MD 97–007 Preventive Medicine MD 97–012 Veterinary Services

G. COMMAND, CONTROL, AND COMMUNICATIONS

1. Scope

Command, control, and communications (C^3) are key elements in the AMP to change the Army from an industrial age force to a digitized Force XXI that is prepared to fight and win the information war. C^3 encompass many interrelated technologies and specialties with emphasis in three major areas: decision making, information management and distribution, and seamless communications.

2. Rationale

Access to and exploitation of timely information is a key element of America's future warfighting and crisis management capabilities, as well as of its national competitiveness. The projected force-level-multiplier advantage of information technology stands far above that of all other technical areas. Such capability, while greatly enhancing the autonomy and survivability of individual units, will quickly provide an advantage in any conflict, supporting early, decisive victory with minimal cost in assets and human life.

Decision making is the heart of the command process and has the following areas of focus: consistent battlespace understanding; forecasting, planning, and resource allocation; and integrated force management. It encompasses the development of common, modular elements that connect joint mission planning, rehearsal, execution monitoring, and common pictures of the battlespace.

Information management and distribution provides the information infrastructure and products needed for information security, distributed computing, distributed multimedia databases, and visualization. This movement of information is critical to satisfying the warfighters' needs for the future.

Seamless communications supports split-based operations by spanning the globe and interconnecting command echelons, services, and allies worldwide through common transport protocols and dynamic network management. Emphasis is on mobility aspects of communication networks, network management, and heterogeneous transmission systems (e.g., wired and wireless). By focusing on wide bandwidth capabilities linked to our narrowband tactical systems, we can provide the correct critical information to the warrior anywhere in the world.

C^3 programs will develop the technology to provide a real-time, fused, battlespace picture with integrated decision aids. The technology will provide the processing infrastructure, intelligent/anticipatory data manipulation and distribution, and dynamically adaptive broadband communications linkages required for both command and sensor-to-shooter applications. Warfighters will be able to exchange information unimpeded by differences in connectivity, processing, and interface characteristics. With these capabilities the Army will have the ability to establish distributed, virtual staffs that share a common, consistent perception of the battlespace.

Many of these advances in information science and technology (IS&T) are being driven by commercial developments and products. The results can be brought to bear on Army problems through cooperative efforts and participation in efforts to set standards and establish policy. Costly Army-specific development will be avoided with the amortization of costs across government and commercial communities. The Army strategy also includes leveraging DARPA programs (such as global mobile information systems and small unit operations (SUO) technology programs) to the extent possible. However, there are aspects of C^3 that must be strongly influenced or directly supported by the Army. In particular, developing the capability to reliably communicate to and among numerous, widely dispersed mobile sites operating in actively hostile environments, identification friend and foe (IFF), achieving information security, and meeting the requirements for military-unique processing and

decision support systems will not be achieved without significant Army support.

This technology area embodies enormous dual-use potential in numerous areas vital to economic competitiveness and other national concerns. Beside the direct application of this technology to defense sciences and engineering, it has great potential for other significant contributions: more effective health care procedures, enhanced education and lifelong learning, more timely and less costly procurement through electronic commerce, more efficiently managed and integrated transportation networks, delivery of innovative information services to average citizens, and sound methods of environment monitoring, weather prediction, and pollution control.

3. Technology Subareas

a. Decision Making

This subarea focuses on all elements of the decision making process, from tactical assessment through plan preparation, deconfliction, rehearsal, and execution. The major emphasis is on acquiring and assimilating information needed to dominate and neutralize adversary forces. A key capability is near-real-time awareness of the location and activity of friendly, adversary, and neutral forces throughout the battlefield area, providing a common awareness of the current situation. One of the primary objectives of information dominance is to meet the warfighters' needs for a flexible command structure that can be rapidly configured and dynamically adapted to optimize force effectiveness and survivability. The subarea applies leading-edge M&S and computing and software technology to significantly improve warfighter performance by eliminating laborious, time-consuming manual procedures and processes that pervade U.S. operational planning and execution. Computer-aided processes and automation-synergistic procedures replace exclusively human processes and procedures. The warfighter is provided with an intuitive view of battlespace, an enlightened perspective of information (C^2, intelligence, logistics, weather, and other critical data), and the ability to explore alternatives in faster-than-real time (e.g., exploring 10-hour battles in several minutes).

Goals and Timeframes

The goal is to provide automated, real-time decision support to the warfighter. The warfighter must rapidly interpret information received through interactive 2D and 3D presentations of the tactical situation (situational assessment cues identifying potential problems or interest areas). The commander must view (from a situational assessment display) relevant forecasts for weather, enemy strength over time, friendly strength, and logistics tail; conduct course of action analysis; allocate resources; wargame (real-time simulation) to explore battlespace options; and collaboratively plan and rehearse battles. Such a capability will result in the precise direction of a diverse, synchronized task force armed with overpowering information superiority and decision making capability.

Major Technical Challenges

The challenges are to develop applications that employ intelligent agents for intelligent information retrieval, fusion, and presentation; fuse planning information with actual information in real time; provide real-time simulation (wargaming), planning, and rehearsal with sufficient fidelity on tactical platforms to influence battle outcomes; provide decision support in the presence of uncertain, incomplete information, or the absence of information; develop applications for dynamic scheduling/coordination of assets for interdependent tasks; and provide collaboration tools that permit the spectrum of operations to be performed by remote, dispersed elements of a task force.

b. Information Management and Distribution

Information management and distribution encompasses warfighter needs and capabilities related to information warfare (IW) and information systems. IW and information systems

include information, information-based processes, information systems, and computer-based systems individually or in combination with each other. The key to providing this capability is a distributed information management and distribution system that forms the backbone information infrastructure of all future command, control, communication, computer and intelligence (C^4I) systems. Providing technologies that allow automated, adaptive, and robust information resource management means we can free up the warfighter from the mundane and tedious tasks required to review and distribute information. By incorporating a context-based approach, information synchronization and management can be formally automated, allowing warriors (especially those at the fighting echelons) to concentrate on mission execution rather than on complex computer operations.

Goals and Timeframes

Required warfighter capabilities for information management and distribution necessitate development in the constituent areas of distributed environments, information services management, and ensured information services. These technology efforts will provide the warfighter with the ability to:

- Access mission-critical data from any location on the globe in a location-transparent manner.
- Collaborate on mission plans at all levels and monitor execution in real time.
- Assess mission plans through rehearsal using synthetic environments.
- Assure continuation of mission critical functions and survive loss of resources by dynamically reconfiguring where functions are executed and how information flows.
- Provide reachback from deployed forces to garrison and support units.
- Support interoperability among both joint and coalition forces.
- Support extension of the information backbone to highly mobile, deployed forces through the integration of mobile distributed computing nodes.
- Maintain access control, authentication, integrity, and availability of classified data in a distributed information environment accessible by users with differing clearances and needs to know.

Major Technical Challenges

The challenges are areas associated with the infrastructure for the distributed environments, mechanisms to support information services management that reside within the distributed environment, and the ability to deploy ensured information services. In the distributed environment infrastructure area the critical technical challenges are:

- Distributed data storage and query.
- Scalability to several thousand nodes and schedulability of time-critical operations that are physically dispersed across large geographic areas.
- Varied user populations and applications.
- Multiple processor types.
- Capabilities and configurations.
- Integration of both real-time and non-real-time operating environments within the same overall system.

As always, compatibility with emerging commercial system standards and heterogeneous computing bases—while retaining DoD's desired operational capabilities—is vital.

Providing the necessary information services management within the distributed environment requires the development of mechanisms for managing data both on individual hosts as well as across the distributed environment. The critical technical challenges to be met include:

- Developing data models and storage and retrieval architectures capable of handling modalities of data in a seamless way.

- Merging and synchronizing time-dependent and non-time-dependent data.
- Developing intelligent agents capable of autonomously navigating complex database structures and extracting information for a user.
- Developing natural language and other nonparametric interfaces to support "intuitive" access and retrieval of data from the database management systems (DBMSs).
- Developing adaptive information distribution techniques based upon context-based as opposed to message-based distribution.
- Using the information context for smart distribution over low bandwidth communications in order to selectively control the quantity of information exchanged.
- Providing capability to respond to complete information exchange failures.
- Scaling information distribution techniques to large systems of communications nodes.

The keys to developing ensured information services are:

- Adaptivity within the distributed environment to allow dynamic response to varying loads of crisis management or system failure.
- Protection of the information within the system from attack or compromise.

The technical challenges include:

- Security mechanisms for multiclustered, real-time heterogeneous distributed environments.
- Adaptivity mechanisms that support the selective application of fault tolerance and fault avoidance strategies.
- Reconfiguration mechanisms to support graceful degradation.
- Replication mechanisms to ensure the consistency of information.
- Intelligent resource managers to dynamically respond to crisis overloads.
- System architectures that permit the secure use of commercial off-the-shelf (COTS) computers, software, and networks.

c. Seamless Communications

Seamless communications facilitate several of the warfighters needs for information dominance, information warfare, real-time logistics control, and MOUT. Communications is the mechanism to achieve secure, reliable, timely, survivable, $C^{2,}$ and superior battlefield knowledge. This subarea addresses technologies needed by the warfighter to obtain effective access to and utilization of global communications services. Seamless communications connotes assured, user-transparent, secure connectivity between globally dispersed sanctuary locations and positions in theater—down to the lowest echelon foot soldier or Marine, and to each ship and aircraft. This connectivity will be accomplished using a combination of U.S. government, foreign government, commercial infrastructures, and military surface- and space-based radio frequency (RF) networks. A range of transmission media, bandwidth, standards, and protocols will be accommodated automatically by the networks. Voice and all types of data (e.g., text, graphics, imagery, and video) will be handled within a uniform, information transport infrastructure. These technologies will provide the commander with high capacity, flexible, tactical communications to serve all categories of users (including mobile) and satisfy the need for high-confidence communications regardless of system limitations throughout all phases of the battle.

Goals and Timeframes

The goal is an affordable, survivable, self-managing, multilevel secure (MLS) communications system that provides the warfighter with user-transparent connectivity for voice and command, control, and intelligence (C^2I) systems

data over the entire combat/garrison operational continuum. The system must fully support wide- and narrowband on-the-move (OTM) C^2I data/voice interconnections throughout a land battle zone at least 100-km deep and provide robust and seamless connectivity among ground, air, and naval elements of the coalition combat force dispersed over distances up to 200 km. Achieving this goal will require significant enhancement of tactical communications systems; development of automated, seamless interfaces between tactical systems and between tactical and global communications systems; development of sophisticated new radio and antenna systems for the airborne and ground OTM portion of the warfighting force; evolution of theater/global broadcast systems as an integral element of seamless communications; and development of artificial intelligence tools for network planning, engineering, management, and operations.

Major Technical Challenges

Challenges in this area include:

- Communications mobility/wireless mobility issues (both nodes and base stations).
- Communications equipment interoperability in multivendor, multinetwork, joint/combined force, and commercial environments.
- Infrastructure for wireless tactical asynchronous transfer mode (ATM) links.
- Protocols for high data rate subscriber loops subject to sporadic disturbances (e.g., narrowband integrated services digital network [N–ISDN] and broadband ISDN [B–ISDN] loops supporting OTM airborne/surface/subsurface vehicles).
- Construction of a fully Internet-compliant, tactical packet network using legacy radios such as Single-Channel Ground and Airborne Radio System (SINCGARS).
- Integration of data and voice over low bit-rate links.
- Heavy multipath and deep fade effects.
- Security.
- Development of network management and control protocols that can withstand the onset of federated and nonfederated jamming attacks.
- Waveforms for low probability of interception (LPI) and low probability of detection (LPD).
- Development of conformal arrays for airborne and OTM antenna applications.
- Waveforms or software programmable radios.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Command, Control, and Communications is shown in Table IV–14.

5. Linkages to Future Operational Capabilities

The influence of this technology area on TRADOC FOCs is summarized in Table IV–15.

Table IV–14. Technical Objectives for Command, Control, and Communications

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Seamless Communication	Demonstrate broadband antenna for multiband applications Demonstrate ground mobile ATM broadcast capabilities Develop and demonstrate Internet Protocol (IP)–ATM hierarchical video routing Demonstrate user friendly, inexpensive security services Demonstrate tactical personal communication system (PCS) capability based on commercial technology	Demonstrate optical control of wideband multipanel, phased array antennas for OTM applications Demonstrate antenna positioners for super high frequency (SHF)/extremely high frequency (EHF) satellite communications (SATCOM) OTM applications Demonstrate next generation PCS technology for Land Warrior applications Demonstrate structurally embedded reconfigurable antenna technology in ground vehicles and airborne applications Demonstrate dynamic network survivability through protocol adaption to external influences (weather, threat, congestion, etc.) Provide virtual, integrated communications systems models for division/corps Demonstrate automated intrusion detection, characterization response, and damage restoral for tactical networks	Demonstrate mobile wireless seamless connectivity across communication media; overcoming differences in connectivity, processing, and system interfaces (Universal Transaction Services) Demonstrate/adapt future generation commercial PCS technology for tactical environments Develop advanced antenna technologies Develop advanced adaptive networking technologies
Information Distribution and Management	Distributed heterogeneous database access Automated information distribution software Distributed computing over low bandwidth channels Machine aided human translation of text for C^2 interoperability	Access to multilevel secure distributed database Integrated, distributed semi-automated C^2 at lower echelons Demonstration of seamless interoperable multilevel secure computing environment Fully automated translation (voice/text) in narrow domain C^2 operations and enhanced natural language machine interfaces	Demonstrate extended relational and object-oriented DBMS system Scalable, transparent mobile computing environment Scalable secure distributed databases Natural language interfaces for synchronized battle management
Decision Making	Terrain, environmental, and event detection decision support software Automated flight plan guidance algorithms Embedded software tools to enable real time collaborative planning in a 3D virtual environment Integrated and automated position/navigation (POS/NAV)	Automated maintenance of consistent, timely tactical picture in distributed C^3 system Automated situation assessment Demonstrate joint distributed collaborative planning and assessment tools with 3D visualization Automated cooperative interaction between three to four systems Robust precision POS/NAV	Robust cooperation Software agents dynamically support collaborative planning and execution Dynamic immersive rehearsal planning and execution environment Autonomous navigation in well-characterized terrain Adaptive tactical navigation

Table IV–15. Command, Control, and Communications Linkages to Future Operational Capabilities

Technology Subarea	Integrated and Branch/Functional Unique Future Operational Capabilities
Seamless Communications	TR 97–002 Situational Awareness TR 97–007 Battlefield Information Passage TR 97–008 Power Projection and Sustaining Base Operations TR 97–009 Communications Transport Systems TR 97–010 Tactical Communications TR 97–011 Information Services TR 97–015 Common Terrain Portrayal TR 97–019 Command and Control Warfare TR 97–020 Information Collection, Dissemination, and Analysis TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–022 Mobility—Combat Mounted TR 97–023 Mobility—Combat Dismounted TR 97–028 Unmanned Terrain Domination TR 97–029 Sustainment TR 97–050 Joint, Combined, and Interagency Training TR 97–056 Synthetic Environment
Information Distribution and Management	TR 97–001 Command and Control TR 97–005 Airspace Management TR 97–006 Combat Identification TR 97–007 Battlefield Information Passage TR 97–008 Power Projection and Sustaining Base Operations TR 97–009 Communications Transport Systems TR 97–010 Tactical Communications TR 97–011 Information Services TR 97–013 Network Management TR 97–015 Common Terrain Portrayal TR 97–016 Information Analysis TR 97–017 Information Display TR 97–019 Command and Control Warfare TR 97–020 Information Collection, Dissemination, and Analysis TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–022 Mobility—Combat Mounted TR 97–028 Unmanned Terrain Domination TR 97–029 Sustainment TR 97–049 Battle Staff Training and Support TR 97–050 Joint, Combined, and Interagency Training TR 97–056 Synthetic Environment
Decision Making	TR 97–003 Mission Planning and Rehearsal TR 97–004 Tactical Operation Center Command Post TR 97–006 Combat Identification TR 97–007 Battlefield Information Passage TR 97–012 Information Systems TR 97–014 Hands-Free Equipment Operation TR 97–016 Information Analysis TR 97–018 Relevant Information and Intelligence TR 97–019 Command and Control Warfare TR 97–020 Information Collection, Dissemination, and Analysis TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–022 Mobility—Combat Mounted TR 97–029 Sustainment TR 97–048 Performance Support Systems TR 97–049 Battle Staff Training and Support TR 97–050 Joint, Combined, and Interagency Training TR 97–056 Synthetic Environment

H. COMPUTING AND SOFTWARE

1. Scope

The Computing and Software technology area is focused on novel computer hardware, software and integrated systems for Army applications. The Army's computing technology programs include scalable parallel systems and applications, high-performance specialized systems and applications, networks and mobile computing, and wearable computers. The software technology programs include software engineering, data engineering, artificial intelligence (AI) and intelligent agents, human–computer interface, assured computing, distributed interactive computing, and information processing systems, computers, and communications. Our ability to rapidly adapt these technology capabilities to changing battlefield environments is an integral part of the technology edge needed to provide decisive victory for the *Army After Next*.

The challenge is to identify efforts that preserve, extend, and leverage the Army's past, present, and future investments in software. The Army views integrated battlefield information systems and intelligent weapon systems as two of its most important sources of combat advantage into the next century. Yet, the software to support such integrated systems represents a challenge to conventional engineering, procurement, sustainment, and technology insertion practices.

Software technology encompasses a wide spectrum of highly technical specialties, activities, and processes, including, but not limited to, the following:

- Develops and produces algorithms and tools for the construction, operation, and life-cycle management of general-application software and all of its associated artifacts.
- Is concerned with all aspects of software engineering and life-cycle management.
- Includes the software engineering process and methodologies, tools, and frameworks (software environments) and domain-specific software architectures (DSSAs) to make it easier to design, build, test, and maintain software.
- Supplies the software building materials used to make software systems more reliable, uniform, predictable, and suitable for reengineering and reuse efforts.
- Includes information and data engineering that provides timely access to quality coordinated technical information.
- At its foundation, applies the general software engineering paradigms to "work smarter" (through process technology advancements), "work faster" (through advancements in tools and environments), and "work less" (through architectural and reuse technology advancements) to provide a technical environment for more intelligent and efficient application specific engineering.
- Ultimately provides intelligent systems capable of integrating information, human–computer interactions and general-application software engineering functionalities to meet the real needs of the soldier on the battlefield (see Figure IV–5).

2. Rationale

The Army relies on technologically superior systems to counter numerically larger forces, to reduce casualties and damage to urban infrastructure, and to enhance rapid, decisive action. Coupled with sophisticated applications software, high-performance computing (HPC) systems and advanced communication technology enable:

- Design and optimization of smarter, more cost-effective precision weapons.
- Rapid dissemination of battlefield information to tactical forces.
- Swift, global C^2 based on accurate, comprehensive knowledge of the current situ-

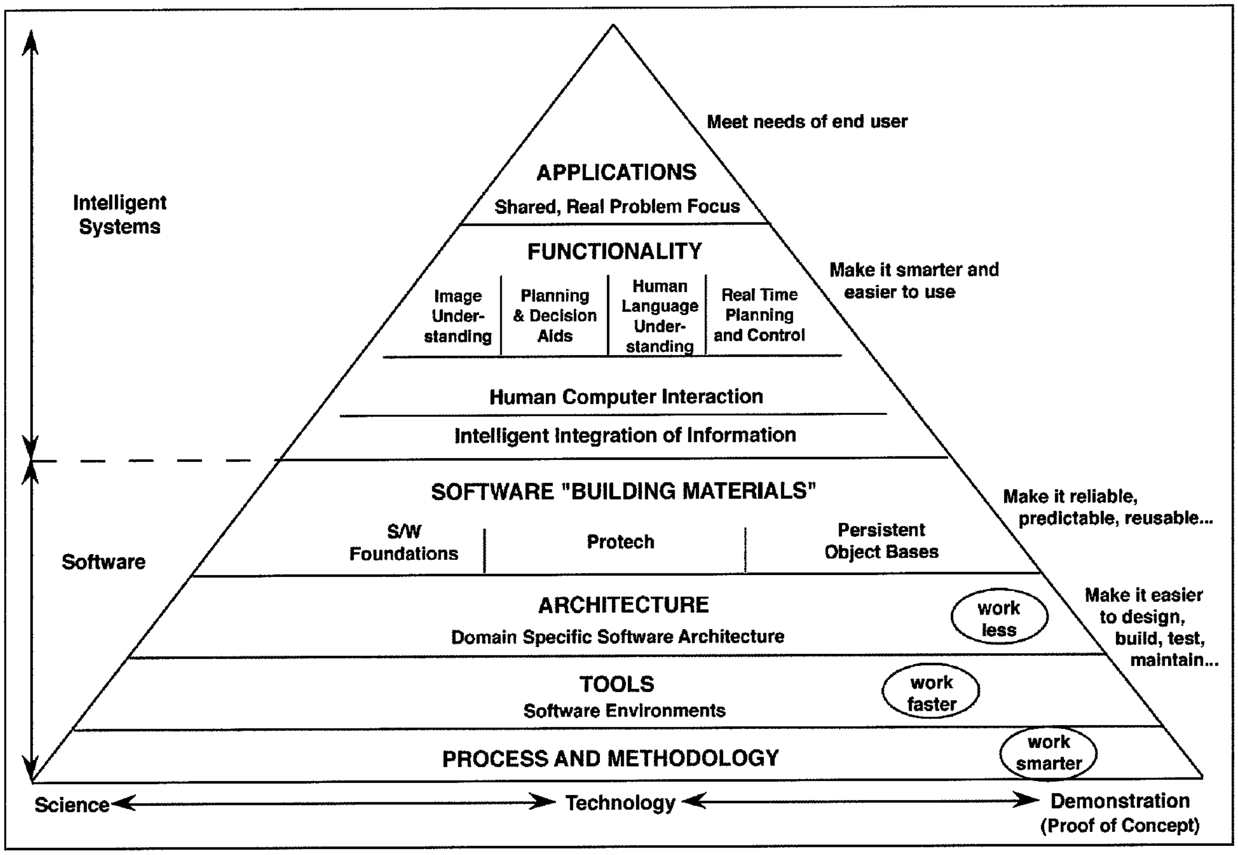


Figure IV–5. DoD Software and Intelligent Systems Program

ation, which greatly enhances the autonomy and survivability of individual units.

- Enhanced readiness and strategic planning capabilities through large-scale, distributed, authentic simulations.
- Enhanced tactical planning and decision making capabilities through the use of automated decision support tools, increased battlefield visualization capabilities, and intelligent agents.

Research in this technology area encompasses computer and software engineering, operational simulation, battlefield environments, and science application tools.

Many Army S&T problems require computational performance rates measured in trillions of floating point operations per second (teraflops). These include problems in chemistry and materials science, computational fluid dynamics, parametric weight/vulnerability reduction, automatic target recognition, high-performance weapon design, and dispersion of hazardous materials. Since no single HPC architecture will effectively handle this spectrum of problems, Army S&T researchers require a variety of computer systems that, in aggregate, support the highest fidelity and greatest speed in analyzing problems of ever increasing size and complexity. These diverse S&T applications also require massive, hierarchical data storage and scientific visualization capabilities to provide meaningful results. HPC utility will fundamentally drive or limit solutions to these critical problems.

The profound impact of modern, computer driven technology has been amply demonstrated in recent hostile operations like Desert Storm and Joint Endeavor. Software is, and will continue to be, a force multiplier.

The Army is faced with a paradox. Systems are being extended in life and expected to achieve land force dominance with diminished resources, in a changing world, with a reduced defense industrial base. Yet, the Army is expected to field lethal, versatile, and rapidly deployable systems in response to the requirement to win decisively and quickly on any battlefield and to do so with minimum casualties.

Computer resources in general and software resources in particular offer a solution to this paradox. The U.S. defense strategy continues to be dominance based on superior technology. But changes in the world's geopolitics combined with current economic constraints has broadened the focus of attention on technology to include issues of flexibility and adaptability. In today's weapon system technology, software serves the role of providing these characteristics. Therefore, weapon systems will become more dependent on software to achieve these requirements. According to the Chief of Staff, Army, one of the most important lessons apparent from the Army's performance in Operation Desert Storm was the profound impact of modern, computer driven technology on the outcome of battle. Desert Storm demonstrated the need to adapt and deploy the technology when and where it is needed.

The Army's challenge is that existing hardware/software systems are being extended to achieve dominance through increased capability, while resources for that capability continue to shrink. Much of the evolving capability is provided by software. A change in hardware through product improvement has all the appearance of a new item while a change in the software supporting that hardware is not viewed as a new item. This visibility mismatch furthers the gap between the perceived and actual costs of hardware and software sustainment. The goal of the Army software S&T effort is to reduce software development and sustainment cost and schedules by an order of magnitude in the next 10 years, while increasing the capabilities of the software industrial base to allow more to be done with less.

Software allows for short lead times and can be deployed over satellite communications links with essentially no logistics volume, weight, or fuel cost. State-of-the-art training technology can provide expert systems that can train soldiers to use the new software on the battlefield. Changes to deployed systems can feasibly be made in theater through software modifications that have been previously tested in the Army's stateside life-cycle software engineering centers (LCSECs) where synthetic environments, interacting with real materiel, are used to demonstrate successful performance of the changed system.

With technology progressing at a rapid pace, the dilemma is that systems that are state of the art today become enormous cost burdens in the near future. Some systems deployed today and still in production require dated software maintenance and change techniques that are frozen in time and appear to be enormously expensive to sustain (e.g., interoperate, respond to threats). Yet, the cost to make these changes in hardware, produce new hardware, refurbish materiel, and redeploy would be even more unacceptable.

The Army recognizes that research and development (R&D) in software engineering and life-cycle management and environments are to a large extent commercially driven. Systems currently under development and the employment of advanced concepts and operational scenarios that have a greater reliance on synthetic environments will exacerbate the current dilemma faced in supporting deployed software. A paradigm shift is required in the way that software is viewed, supported, and developed. Decreased budgets will increase reliance on commercial products, and possibly increase costs. It is imperative that we learn to leverage commercial advancements, while continuing to provide some level of support to maintain an industrial base in the software development market.

The Army software technology investment strategy represents the distillation of extensive

work performed by technical experts from industry, academia, and government to create such a scenario. The work plan is focused on the needs of the Army, windows of opportunity, and a realizable implementation, given limited resources.

3. Technology Subareas

a. Scalable Parallel Systems and Applications

Goals and Timeframes

This subarea is concerned with development, exploitation, and deployment of high-performance computers offering scalable performance for a broad range of Army and DoD applications. Scalable parallel systems technology includes parallel architectures, compilers, and programming methodologies and tools essential to facilitate their effective use, systems software, mass storage, input/output (I/O), and visualization technologies. Application requirements drive the design of these systems.

Early access to new systems by DoD and Army users accelerates development of specific applications as well as knowledge, algorithms, and programming tools for solving problems. Current performance levels of 100 billion of floating point operations per second (gigaflops) will sustain a 10-fold increase by FY98 to reach the goal of 1 teraflop.

The Army relies on the DoD HPC modernization program to provide computing capabilities essential for the conduct of RDA and in support of the operational forces. The Army manages and operates two DoD HPC major shared resource centers (MSRCs) and five distributed centers (DCs) within the DoD modernization program. The Army MSRCs are located at the ARL Aberdeen Proving Ground (APG) and the Army Corps of Engineers Waterways Experiment Station (WES), which combine to offer full service HPC capability and high speed network access to both the DoD S&T and test and evaluation communities and the national HPC infrastructure.

The capabilities provided at the Army MSRCs are directly aligned to the DoD following objectives:

- Increase the availability of the state-of-the-art HPC resources and supporting infrastructure for DoD R&D scientists, engineers, and analysts.
- Provide robust interconnectivity to these resources, the user community, and non-DoD collaborating scientists and engineers.
- Develop and adapt software tools and applications to fully exploit HPC capabilities.
- Actively engage other national HPC programs and leverage them to benefit defense R&D.
- Focus national leading-edge HPC research efforts in computing, high-performance storage, software development, and networking to solve DoD S&T challenges.

Major Technical Challenges

Deployment of state-of-the-art HPCs and exploitation of evolving computational algorithms provide an environment that allows the Army to solve critical mission problems and to tackle problems that were previously intractable. Improved HPC capability shortens design cycles and design costs by reducing the reliance on handcrafted prototypes and destructive testing. Robust high-speed network connectivity is essential for desktop access to remote resources and daily, interactive collaboration with remote users.

Issues include:

- Insertion of increasingly powerful processing nodes.
- Faster interprocessor communications.
- Global management of memory and data in cooperation with the operating system.
- Scalable I/O processing to match processor speeds.

- Software and application development.
- The learning curve for Army users when programming in a massively parallel environment.

b. High-Performance Specialized Systems

Goals and Timeframes

The high-performance specialized systems subarea includes the development of innovative technologies such as optical processing, embedded systems, neural networks, and systolic processing, that meet military requirements but have limited commercial potential. Target goals for these systems include a 200-fold increase in data processing reliability, a 10-fold system weight reduction, and a 5-time increase in digital data processing speed. The Army relies on DARPA and the other services to provide technology for its systems applications.

Major Technical Challenges

The diverse deployment criteria for specialized Army systems makes hardening and repackaging essential. In addition, image and speech recognition dictates that DoD and the services examine optical processing and neural computing. Incorporating fuzzy logic into neural computing for Army problems requires further research into expressing expert knowledge and combinatorial complexity in simple linguistic rules while reducing demands on computing resources.

c. Networks and Mobile Computing

Goals and Timeframes

Real-time access to information and data is required to realize one of the Army's key modernization strategies of "winning the information war."

Integral to this capability are the computing and networking capabilities required to provide a secure and seamless battlefield computing environment. These capabilities include instant access to data, data extraction of the desired information in near-real time, and retrieval and presentation of the information in a form that the soldier can readily use to make educated decisions and better control the available resources. These capabilities require integrated networking of battlefield and research-based computing systems. High-speed and high-capacity networks enable interaction with research-based computing assets.

Networking has long been a mechanism to foster scientific collaboration, and the services were launched into this realm by the ARPANET initiative of the 1970s. This DARPA program has grown to be integrally responsible for the Internet explosion that serves as the catalyst and foundation for the National Information Infrastructure project. Ten gigabit (GB) per second to 100-GB per second networking will be available by the year 2000.

As part of the DoD HPC modernization program, the Defense Research and Engineering Network (DREN) is being designed to maintain intersite communication performance levels commensurate with I/O bandwidths of the HPC systems to which DREN will provide access (Figure IV–6). Bandwidth requirements are projected to approach 622 megabits per second (Mbps) within 2 to 3 years, and over 1 gigabits per second (Gbps) within 5 years to support and enable distributed computing performance in the TFLOPS range. These requirements represent an order of magnitude (x10) increase over currently available bandwidth within 1 year and more than two orders of magnitude (x100) increase over current bandwidths within 5 years.

The Army provides the technical lead in maintaining the interim DREN (IDREN) connectivity through transition to the DREN component of the DoD HPC modernization program. Current Army mission projects in networking include, but are not limited to:

- B–ISDN and ATM experiments over a NASA advanced communication technology satellite (ACTS) conducted in

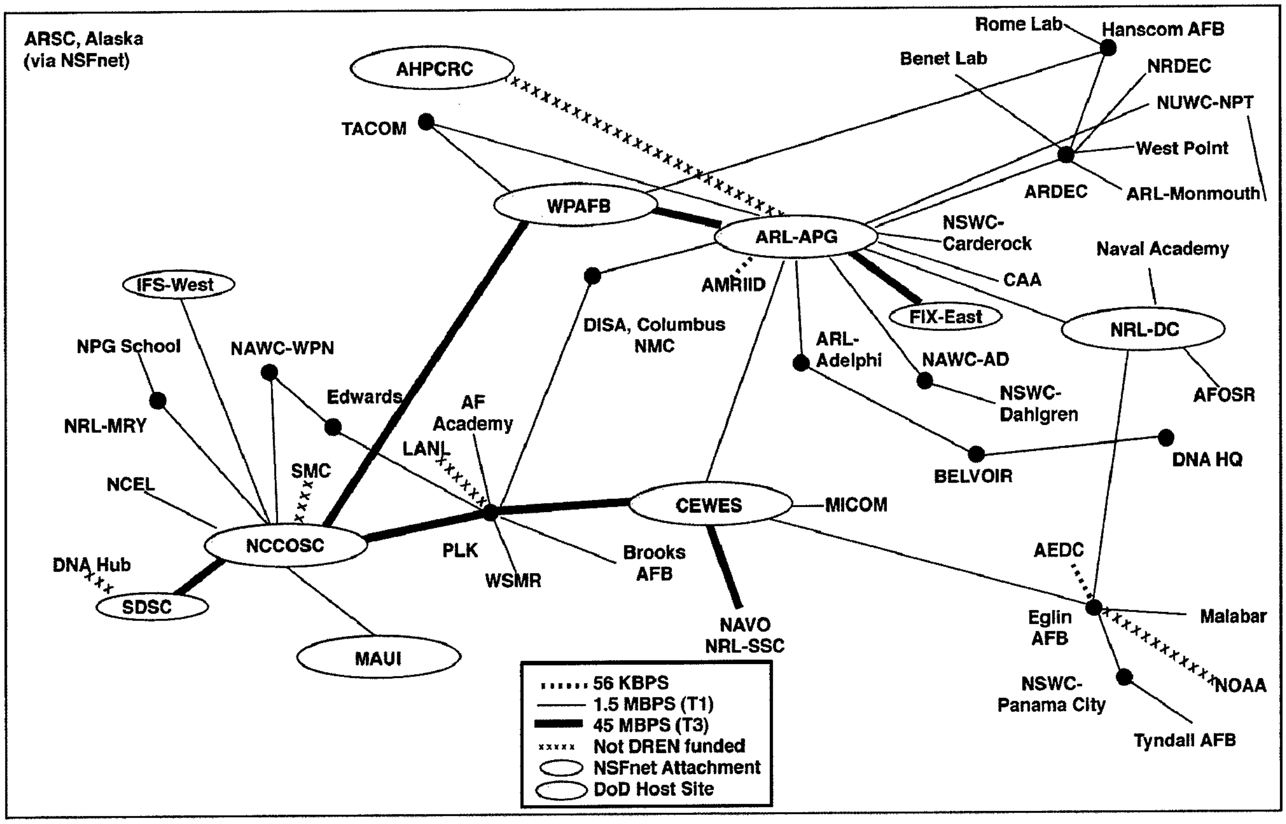


Figure IV–6. IDREN Configuration

order to develop high-bandwidth digital communications over widely separated local area networks (LANs) to allow widespread access to expensive resources (ongoing).

- Wireless LAN for testing of COTS high-bandwidth equipment carried out to find wireless LAN best suited for distributed simulation communication, and for fast setup/teardown of military sites (FY96).
- Video, interactive graphics, and telecommunications over a desktop workstation and personal computer (PC), and adaptive compression schemes allowing high data rate communications between distributed users.
- Executable protocol specifications using very high speed integrated circuit (VHSIC) hardware descriptive language (VHDL) to replace ambiguous English language specifications with an unambiguous computer language specification to ensure that various COTS/government-off-the-shelf (GOTS) telecommunications equipment will be interoperable (FY97).

Major Technical Challenges

The challenges include recognizing and identifying the most promising commercially available technologies and products and adapting these to Army needs. Since the environment and the conditions used in the commercial and military sectors are not the same, some adaptation may be required, especially in four areas: sensing, analysis, distribution, and assimilation. These factors turn combat information into knowledge, described by mathematical algorithms, and distribute the information in a hostile battlefield environment. The objective is to provide real-time, knowledge-based operations and seamless battlefield communications and computer pro-

cessed C^3I electronic warfare (EW) throughout the operational hierarchy.

Technical issues being addressed include protocols for reliable, seamless connectivity as remote hosts increase in number and explore high-bandwidth data channels to offset the need for large-scale localized data storage. Security and data integrity issues are also of interest as well as the configuration optimization, mobility and robustness of the computing systems.

d. Wearable Computers

Wearable computers and their applications are starting to become feasible. They can act as intelligent assistants and may take many forms, from small wrist devices to head-mounted displays. They have the potential to provide anywhere, anytime information and communications. Applications such as telemedicine (augmented reality), memory aids, maintenance assistance, distributed mobile computers in wireless networks (individual communication with soldiers on the battlefield), and desktop applications such as word processing, scheduling, and database applications.

e. Software Engineering

The Army software technology investment strategy (ASTIS) is a targeted strategy based on a principle that capitalizes on conditions of imperfect competition with our adversaries and rapid technological change. Stated in warfighter terms, hit them where we are strong and they are weak, with the technology transfer equivalent of overwhelming force. The ASTIS vision includes:

- Minimize software cost and schedule drivers in DoD systems.
- Maximize the use of commercial best practice and products.
- Evolve systems and infrastructure.
- Enable greater mission capability and interoperability to exceed expectations of the soldier in the field.

This vision is realized through the establishment of a virtual advanced software technology consortium (VASTC). Assets of a VASTC will be a distributed matrix of an integrated government, academic, and defense industrial software and computer resource asset base.

The word "virtual" in VASTC implies:

- An idealized machine, a technology transition engine, interconnected real assets that act like a technology center in one physical location, and one organization—a rich matrix of diverse collaborating entities that act as if they were one.
- An enormously flexible network, a consortium with the illusion of being an organization that can dynamically change.
- The VASTC is designed to get the right technology to the right customer, virtually on demand.

A roadmap establishing, prototyping, demonstrating, and scaling up incremental capabilities hinging on this principle will yield an emphasis and a paradigm shift. Each effort in the roadmap has building blocks of integration, process, product teams, and a paradigm shift built in. The result will create a distinct techno-economic paradigm built around flexibility rather than simple volume production.

The ASTIS strategy consists of:

- *Process*—transition technology for affordability
  - Focus emerging software process technology
  - Integrate discrete technologies
  - Mature the Army's supporting infrastructure
- *Product*—domain/product line management and horizontal technology integration
  - Evolve common components
  - Converge to domain-specific architectures

 - P^3I of legacy software
 - Establish software exit criteria for ATDs
- *People*—professional development of the matrix
 - Government
 - Industry
 - Academia
- *Paradigm*—the integrating concept (VASTC)
 - Focused expertise and technology
 - Prototype software technology incubators
 - Integrated distributed incubators
 - Life-cycle software engineering center of the future.

The ASTIS guides the industrial base toward key critical technology sectors. These sectors include computers and software support for the development of capital goods such as aircraft, ground transportation vehicles and systems, flexible manufacturing facilities, as well as telecommunication, decision support, visualization, and battlefield information systems. These are the sectors having the greatest growth and technological potential.

Virtual Advanced Software Technology Consortium

Goals and Timeframes

The VASTC offers industry and academia distributed yet integrated advanced technology transfer incubation facilities in which the emerging technologies come together to enable risk reducing proof-of-principle demonstrations conducted with access to materiel in an operational environment. This enivronment enables evolving synthetic environments, a distributed high-performance computing infrastructure, and advanced large-scale program management techniques. The VASTC establishes a rapid software technology transition channel for the Army and the nation.

Figure IV–7 depicts a single software technology incubation cell. The VASTC incubators scale up immature, emerging, and mature technologies, and integrate these technologies into existing environments. Real systems are the test articles and have the beneficial side effect of reducing risk on the actual programs. Deployed (in-service engineering), new developments, and

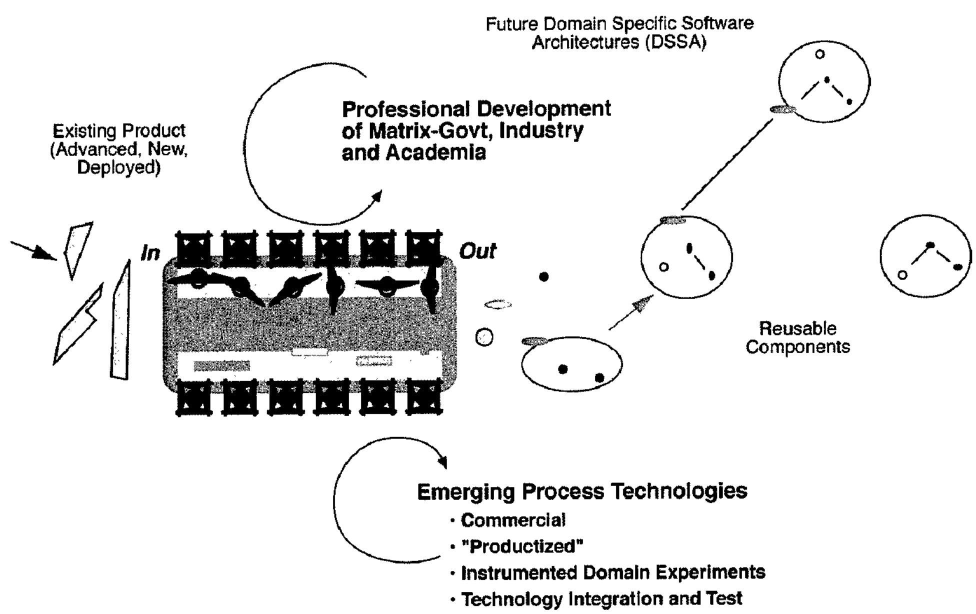


Figure IV–7. Software Technology Incubator Concept

advanced concept systems provide scale-up opportunities and real-world challenge problems. Yet, the artifacts from the incubators are reusable components that are targeted to domain-specific software architectures.

The VASTC offers the government an engine to continuously reduce risk and insert technology into existing weapon system software. The VASTC is also a software technology training factory. People are educated and trained in the use of the new technologies while they are analyzing and modernizing existing systems. The software training factory operates on existing systems with new technologies. The VASTC training factory will optimize resources and reduce risk by acting as a booster to future builds of existing systems.

Regardless of a VASTC participant's role (e.g., academic, principal investigator, independent R&D (IR&D) explorer, governmental staff developer), the technology will flow with the participants. The VASTC will be a national asset and an engine of technology transfer influencing commercial practice that will be reflected in government products.

Major Technical Challenges

Key to realizing the vision of the VASTC will be the capability to provide integrated automation capabilities throughout the software life cycle. Process automation is a relatively new area of research with many technical challenges. A common underlying infrastructure that allows ease of integration and supports evolutionary development for each individual technology being automated will be necessary. Early efforts will be directed at developing this underlying infrastructure and providing an open interface that encourages tool vendors to build tools that support VASTC. Long-term efforts will be directed at finding technological advances that will make a seamless automated software development paradigm a reality.

Next-Generation Life-Cycle Software Engineering Center

Goals and Timeframes

The amount of Army software (old, modified, new) requiring life-cycle software engineering services is increasing exponentially along with life-cycle costs. To address this issue and bring costs under control, the Army has initiated a conceptual shift in how future life-cycle engineering services will be accomplished. At the core of this initiative is the next-generation life-cycle software engineering center (NGLCSEC) prototype. The goal of this new center is to reduce weapon system software development and support costs by at least an order of magnitude. The goal will be achieved by creating a seamless software engineering directorate within the Army Materiel Command (AMC) that shares resources, knowledge, and best practices among its members, with a focus on the customer. The concept is being prototyped at the Tank–Automotive and Armaments Command (TACOM) and scaled to an AMC-wide infrastructure capable of supporting Force XXI and the *Army After Next.*

Major Technical Challenges

Networking systems that can support greatly increased throughput, a supportable infrastructure, and mature domain-specific architectures must be sought out to fully achieve interoperability between geographically dispersed member organizations. Also, new management processes will be needed that can adapt to the many systems supported by member organizations and their organizational cultures.

Requirements Validation

Goals and Timeframes

All software systems are requirements driven. Software users have specific and general needs that must be fulfilled by the software they procure. In order for these software systems to satisfy those needs, the systems must satisfy the formal requirements outlined by users and engineered by designers. Automated systems that

can analyze a software system's formal design to validate the requirements are needed.

Embedded software packages, like software for aircraft control, are critical in the sense that if they fail, soldiers die. Battlefield information systems are critical because they provide critical information to the commander on the scene that facilitates sound decision making.

Major Technical Challenges

Some software requirements are difficult to specify. Methods for formal specification of these requirements are needed to enable automated validation.

Computer-Aided Prototyping

Goals and Timeframes

Computer-aided prototyping is an evolutionary software development paradigm that involves the end user of the software in the requirements development process. This paradigm makes use of prototype demonstrations and user feedback to iteratively develop a functional prototype. Prototypes are executable specifications of software systems partially generated and partially built from atomic components retrieved from a reuse repository. Current efforts are directed at maturing and commercializing this technology to enable practical use by the life-cycle software engineering centers in the research, development, and engineering centers (RDECs). Our goal in FY98 is to continue the maturation of this technology and support its commercialization and incorporation into the NGLCSEC.

Major Technical Challenges

Computer-aided software engineering tools are difficult to commercialize. The long-term investment required to keep these tools viable in the software market is tremendous. Tools like computer-aided prototyping tools are important for the realization of the ASTIS vision, but are not attractive for the software industrial base. Efforts need to be concentrated on supporting their commercialization and influencing the industrial base to champion this technology.

Rapid Prototyping for a System Evolution Record

Goals and Timeframes

Future system development will require vast amounts of data to be collected and made available throughout a system's life cycle. A system evolution record (SER) is needed to serve as a cradle to grave repository for all artifacts and decisions made during the evolution of a software system. An initial model of a SER is being implemented. Our goal for the next and subsequent years is to model different pieces of the software development process to integrate with the SER.

Major Technical Challenges

New techniques for capturing design decisions must be developed to allow for the linking of these design decisions into the SER. Hypergraphs (nonlinear representations of information) must also be developed that will store not only the artifacts to be contained in the SER and the decisions already mentioned, but also dependencies between them. Additionally, new technologies for sharing information like the World Wide Web must be exploited to enable sharing of critical life-cycle information over extended distances.

f. Artificial Intelligence

Goals and Timeframes

Exploiting emerging high-performance computing, storage and retrieval, and communications systems for the Army's electronic battlefield (EBF) requires advanced software capabilities incorporating AI. After 2000, DIS software capabilities are expected to include cooperating intelligent systems, coupling of symbolic and neural processing, and autonomous synthetic agents and robots. This will provide a large synthetic computing environment in which networking and process management are handled automatically and are transparent to the users. This

includes multi-level secure data routing, loci of computation, workload partitioning, and interconnection of government and industry/academia expert and information centers with built-in ownership protection. By 2010, planning systems capable of complete support of military operations and deployment with less than 24 hours notice will become available.

The Army federated laboratory is focusing basic research in five areas, each of which will need AI technologies. These areas are advanced sensors, advanced and interactive displays, software and intelligent systems, telecommunications and data distribution, and distributed interactive simulations. Three approved consortia will work on Army-specific basic research over the next 5 to 8 years. The Army Artificial Intelligence Center manages the Army Artificial Intelligence Program, which is focused on applied research and prototyping to deliver artificial intelligence solutions in support of Force XXI and AAN. A number of expert systems have been delivered, and emerging technologies such as fuzzy logic, neural networks, and generic algorithms are being used to build advanced technologies.

Major Technical Challenges

The study of AI has produced advanced technologies in three categories: mature, emerging, and immature. Expert and rule-based systems are examples of mature technologies that are being widely used in commercial applications. The major challenge is to develop prototypes for Force XXI and identify appropriate technology insertion in existing systems and systems under development. Fuzzy logic, genetic algorithms, and neural networks are examples of emerging technologies. The development of prototypes for exploratory development and risk mitigation will clarify the technical issues. Finally, intelligent agents and machine learning are examples of immature technologies. These are the focus of the basic research efforts in the Army federated laboratory.

g. Human Computer Interface

Goals and Timeframes

Human–computer interactions deal with the systematic application of scientific knowledge about humans to design the simulated human and its behavior as well as the interface software through which real humans interact with the synthetic environment. The Army programs addressing the physical human-machine interface and the human engineering aspects are described in Section III–N, "Human Systems Interface." Information display and human computer communications technologies are steadily advancing. COTS user interface management tools, standards-based approaches for product development, style guides, and graphical information visualization are now available for commercial and military applications. The Army programs addressing human computer interactions rely on these general tools to make computers and associated networks easier to use as well as to build. This is a continuous process.

Major Technical Challenges

An important aspect is the adaptation and interface of the large number of previously developed application-specific closed architecture codes with the COTS human-computer interaction tools. Connected speech systems with increasing natural language interpretation and voice recognition that can be trained quickly for different voices are appearing, but they lack robustness for military applications. Group system capabilities are needed to provide for multiuser interfaces in to software systems, and for group decision making capabilities in battlefield planning systems.

h. Assured Computing

Goals and Timeframes

Safeguarding of information, loss-of-service protection, and damage prevention to programs and data through errors or malicious actions requires multilevel security, defense against malicious software, and credible procedures for

technical evaluation, certification, and accreditation of software. The Army relies on the National Security Agency (NSA) to provide the required assured computing technologies.

Also relevant to this category is the short-term year 2000 problem. Essential management information systems must continue operation through January 1, 2000.

Major Technical Challenges

The biggest challenge facing the assured computing field is the year 2000 problem. Time has nearly run out for developing automated tools to find a solution to this problem, or to develop new systems to replace all legacy systems that display the problem. Manual editing methods will be necessary to solve the problem, and that means manpower. Effective means of keeping critically short software professionals in the Army to solve this problem must be developed.

i. Distributed Interactive Computing

Goals and Timeframes

Instant access to information on computer systems throughout the world is now a reality. Surfing the Web has become a national pastime for Internet users in and out of the government. The Web provides the capability for anyone with access to the Internet to access information on every imaginable subject at any time of the day or night, and on any machine that contains a Web server. This technology is being exploited in many ways to increase information sharing between agencies and to further our movement toward a paperless Army. Web servers have been established at virtually every organization that provides information or services to the Army. Publications and forms have been made available electronically and policies should encourage the use of electronic forms and publications.

This is a relatively new area of investigation and definitive near-, mid-, and far-term goals are still in the early stages of formulation. The tremendous rate of growth in Web technologies offers the promise of many significant advances within a very short time. Army planning will, in part, be driven by the rapid changes in available marketplace technologies.

Major Technical Challenges

The most critical challenge in this area is the ability to provide secure access to sensitive information, allowing easy access to authorized users while preventing unauthorized access. This technology is moving faster than even industry can keep up with. Most of the development of Web applications is being done by hackers working nights and weekends with no wish for compensation. Capabilities for increased information availability and increased interactivity have resulted in our inability to control what information flows and where. Future research must design ways to protect critical information while providing access to necessary information and capability.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Computing and Software is shown in Table IV–16. The Army software program is structured to take advantage of emerging commercial software technologies and relies on the DoD software program for most of the generic software technology, including tools and techniques for software engineering, reuse, and life-cycle management. This program is integrated with the tri-service Reliance program and addresses only those technology areas where DoD program investment will not satisfy Army-specific application needs.

5. Linkages to Future Operational Capabilities

The influence of this technology area on TRADOC FOCs is summarized in Table IV–17.

Table IV–16. Technical Objectives for Computing and Software

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
High Performance Computing and Scalable Parallel Systems	Shared DoD HPC Infrastructure 100 gigaflops performance Gigabyte random access memory (RAM) with microsecond access	Scalable HPC and distributed heterogeneous systems transitioned to the EBF Teraflops systems for S&T arena Multidisciplinary modeling on scalable/distributed HPC	Petaflops systems in S&T labs EBF at 100 teraflops
Networking	DREN and gigabit networking High bandwidth interconnected COTS/digital communications over GOTS telecommunications equipment; separated LANs Wireless LAN testing	10 to 100 gigabit networking Optical wide area network (WAN) testing Telephony integration ATM WAN interoperability Wireless LANs	Ultrafast, all optical WANs Smart switching
Software Engineering	Initial software reuse through rudimentary stand-alone repositories Massively parallel Ada Computer-aided rapid prototyping System evolution record for reengineered systems Virtual life cycle Center implementation	Full-scale reuse through domain specific software architectures and evolvable legacy systems Fully integrated VASTC	Software commerce on demand Integrated capability to develop, field, evolve, and maintain software through VASTC
Artificial Intelligence	Widespread use of AI mature technologies in battlefield systems	Cooperating intelligent systems and symbolic/neural processing included in DIS software capabilities	Intelligent planning systems capable of complete support of military operations and deployment 24 hours a day
Human Computer Interface	Graphical open interfaces for all new software systems fielded	Single user voice recognition interfaces for limited software systems fielded	Multi-user voice recognition interfaces for all Army software capable of filtering out noise interference
Assured Computing	Risk modeling Security properties modeling IW paradigms	Formal specification languages Trusted systems Evaluation criteria for network security properties AI-based intrusion detection Certification of reusable components	Formal reasoning systems High assurance software models Certification methodology and tools for critical properties
Distributed Interactive Computing	Heterogeneous distributed operating systems service (limited capability) Distributed database services over homogeneous databases T1, T3 available	Distributed operating system (OS) services (enhanced capability) Structured query language (SQL) for multimedia database queries Macrobuilding capability Scalable application components	Dynamic reconfiguration for real time (R-T) systems Multiple database, multimedia query capability optimized Interoperable heterogeneous algorithms Automated adaptive load balancing

Table IV–17. Computing and Software Linkages to Future Operational Capabilities

Technology Subarea	Integrated and Branch/Functional Unique Future Operational Capabilities
High Performance Computing and Scalable Parallel Systems	TR 97–001 Command and Control TR 97–007 Battlefield Information Passage TR 97–020 Information Collection, Dissemination, and Analysis TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination
Networking	TR 97–001 Command and Control TR 97–007 Battlefield Information Passage TR 97–011 Information Services TR 97–013 Network Management FI 97–007 Accounting
Software Engineering	TR 97–001 Command and Control TR 97–002 Situational Awareness TR 97–011 Information Services TR 97–012 Information Systems EN 97–001 Develop Digital Terrain Data EN 97–002 Common Terrain Database Management
Artificial Intelligence	TR 97–003 Mission Planning and Rehearsal TR 97–019 Command and Control Warfare TR 97–048 Performance Support Systems
Human Computer Interface	TR 97–002 Situational Awareness TR 97–015 Common Terrain Portrayal TR 97–017 Information Display
Assured Computing	TR 97–001 Command and Control TR 97–008 Power Projection and Sustaining Base Operations TR 97–016 Information Analysis TR 97–018 Relevant Information and Intelligence TR 97–019 Command and Control Warfare
Distributed Interactive Computing	TR 97–009 Communications Transport Systems TR 97–018 Relevant Information and Intelligence TR 97–020 Information Collection, Dissemination, and Analysis TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination

I. CONVENTIONAL WEAPONS

1. Scope

The ultimate goal of all weapons systems is to destroy the target. The conventional weapons technology area develops conventional armaments for all new and upgraded nonnuclear weapons. It includes efforts directed specifically toward nonnuclear munitions, their components and launching systems, guns, rockets and guided missiles, projectiles, special warfare munitions, mortars, mines, countermine systems, and their associated combat control. There are six major subareas: (1) fuzing—safe and arm, (2) guidance and control, (3) guns, (4) mines/countermines, (5) warheads/explosives and rocket/missile propulsion, and (6) weapon lethality/vulnerability.

2. Rationale

Conventional weapons technology strongly supports the needs of the Army in both tactical and strategic mission areas. It responds to the Army's operational needs for cost-effective system upgrades and next-generation systems in support of the top joint warfighting capabilities objectives. Performance objectives focus on projecting lethal or less-than-lethal force precisely against an enemy with minimal friendly casualties and collateral damage. Objectives address the need for the following capabilities: affordable all-weather, day/night precision strike against critical mobile and fixed targets; defense against aircraft, ballistic missiles, and low-observable cruise missiles; effective mine detection and neutralization to permit movement of forces on land; gun/missile systems for advanced, lighter weight air/land combat vehicles and vehicle self-defense systems; lightweight, high-performance gun systems for artillery applications; and precise lethal force projection.

Conventional weapons technologies, when developed and demonstrated, have both an excellent historical record of transition and many future transition opportunities. Examples of the latter include systems currently under development (Crusader, Javelin, line-of-sight antitank (LOSAT), enhanced fiber-optic guided missile (EFOGM)), potential upgrades to existing systems (Patriot fuze), and potential new systems (including intelligent minefield (IMF), precision-guided mortar munition (PGMM), autonomous intelligent submunition (AIS), 155-mm lightweight automated howitzer (LAH), and extended range artillery (ERA) projectile).

3. Technology Subareas

a. Fuzing—Safe and Arm

Goals and Timeframes

Fuzing—safe and arm (S&A) technologies address issues associated with advanced future threats, both air and surface. Primary emphasis is on advanced sensors, signal processing algorithms, guidance integrated fuzing, global positioning system (GPS), miniaturized solid-state components, countermeasure resistance, electronic safe and arm, reliability, and affordability. Major products include an advanced GPS-based artillery registration round in FY98, demonstrations of a standoff fuze against reactive/active armor in FY99 and miniaturized electronic fuzing for objective individual combat weapon (OICW) bursting munitions in FY00, low energy S&A devices in FY03, and low-cost electronic S&A devices in FY05.

Major Technical Challenges

The primary technical challenges for guidance integrated fuzing are in M&S, sensor and signal processing, target characterization, and testing. The challenge for gun munitions is to develop affordable fuzes that will function at the desired point in an adverse environment (electronic countermeasures (ECM)/electromagnetic interference (EMI), obscured targets, cluttered battlefield).

Specific challenges are:

- Construct a guidance integrated fuze (GIF) simulation to provide a common basis for comparing performance of dif-

ferent concepts under given sets of flight dynamics.

- Miniaturize GPS components.
- Integrate RF and IR hardware/software to operate in both guidance and fuze time domains spanning three orders of magnitude (10^3 to 10^6 second).
- Sense a second launch environment for safing and arming nonspin munitions.
- Devise a small generic electronic safe and arm fuze with dual safeties for tank and mortar applications.
- Solve the helicopter-in-clutter problem by developing an electrostatic sensor fuze.

b. Guidance and Control

Goals and Timeframes

Guidance and control (G&C) of conventional weapons is the application of sensors, computational capability, and specific force generation that allows a weapon to engage both fixed and moving targets with improved accuracy and lethality while minimizing collateral damage and casualties. The major milestones are:

- By FY98, demonstrate performance gains in automatic target recognition (ATR) from multispectral sensor fusion.
- By FY98, complete validation of algorithm for combat identification of aircraft utilizing high range resolution radar profiles, electronic support measures, and jet engine modulation.
- By FY98, complete hardware-in-the-loop evaluation of prototype guidance sections of 2.75-inch precision-guided rockets.
- By FY98, demonstrate high-resolution infrared imaging seeker technology through captive flight and flight test. Demonstrate millimeter-wave (MMW) datalink technology packaged on a missile through flight test.
- By FY98, demonstrate, through simulation and both sled and flight testing, a man-in-the-loop fiber-optic guided missile system with a 40-km range.
- By FY99, demonstrate a low-cost, ultraminiature, manufacturable fiber-optic gyro.
- By FY00, demonstrate a strapdown laser seeker and G&C of a precision-guided 2.75-inch rocket.

Some of the specific challenges include:

- Transfer ATR technology into systems.
- Integrate microelectromechanical systems (MEMS) technology into the thrust on precision guidance of small diameter weapons.
- Achieve navigational grade performance with ultraminiature fiber-optic gyros.
- Achieve innovative strapdown designs for laser IR and multispectral seekers.
- Validate static and dynamic target models for combat identification of aircraft.

Major Technical Challenges

The three competency areas in G&C technology (guidance information and signal processing, inertial sensors and control systems, and missile system sensors and seekers) face these major technical challenges: precision guidance of small diameter weapons, enhanced target acquisition, including masked target detection, and operational performance measures for multispectral missile seekers. Responding to these challenges will require the infusion of a number of emerging technologies that are not currently in the G&C program. The G&C program is coordinated with the technical objectives in the manufacturing technology program to achieve manufacturing and producibility goals and extensive use of simulation is made to reduce overall R&D costs.

c. Guns—Conventional and Electric

Goals and Timeframes

The guns subarea develops both conventional and electric gun technologies for all new and upgraded gun systems (small arms, mortars, air/surface combat vehicles, tanks, and artillery). It includes efforts directed toward future, advanced, generic technologies, and system technologies for small, medium, and large calibers, including barrel/launcher, ammunition/projectile, power supply and conditioning, weapon mechanism/ammunition feeder, propellants/ignition systems, and fire control. Products include the OICW prototype in FY98, a demonstration of 14 megajoules (MJ) muzzle energy from a 120-millimeter (mm) M256 cannon in FY99, the integrated objective crew-served weapon (OCSW) system prototype in FY00, the LAH demonstration in FY00, and the PGMM demonstration in FY01.

Major Technical Challenges

Challenges include improving hit probability and lethality on target, extending the maximum range, reducing the weight of the total system, all-weather operation, and reduced barrel wear. Advances in composites, new propellant initiatives, and sophisticated electronics hold promise of overcoming many of these challenges.

Specific challenges include:

- Use composite materials to reduce the weight of individual and crew-served weapons.
- Integrate fuze control for precision air burst on individual and crew-served weapons.
- Enhance ballistic aspects of tungsten materials to provide penetration performance goals with less environmental impact than depleted uranium (DU) material.
- Exploit composites to fashion a cargo-carrying artillery round capable of delivering twice the payload of metal projectiles at current ranges.
- Demonstrate new lethal mechanisms to defeat explosive reactive armor.
- Develop an electrothermal chemical (ETC) tank gun with 18 MJ muzzle energy and 1.9-km/second muzzle velocity.
- Develop tactical size advanced pulse power supplies capable of supporting large caliber ETC and electromagnetic tank guns.
- Demonstrate new propellant architectures and formulations which improve muzzle velocity by at least 25 percent.
- Demonstrate environmentally friendly propellant and process.

d. Mines and Countermines

Goals and Timeframes

The mines and countermine subarea includes all efforts pertaining to the development or improvement of land mines and all efforts pertaining to detecting, marking, breaching, neutralizing, or clearing land mines. The major products include the IMF demonstrating long-range detection/tracking and autonomous, intelligent attack of mobile targets by FY98, a two- to four-fold improvement in individual mine detection for antipersonnel mines and neutralization capability by FY99, a portable, standoff detector and neutralizer for buried antitank and antipersonnel nonmetallic mines at maneuver speeds in FY00, and demonstration of high-speed reconnaissance and breaching of minefields in FY05.

Major Technical Challenges

Challenges include the ability of acoustic sensors to accurately identify and track targets, the maturation of sensor fusion algorithms, and the implementation of tactical response algorithms. Mine detection, neutralization, and minefield breaching have challenges: rapid detection of mines (most false alarms eliminated) and the requirement for 100 percent assurance of removal, destruction, or neutralization.

Specific challenges are:

- Increase mine ability to detect targets during all weather/clutter conditions.
- Extend the mine's sensor range by a factor of four.
- Combine countermine detection and neutralization capabilities.
- Enable robotic (autonomous and semi-autonomous) mine neutralization and extraction.
- Reduce false alarm rate for the detection/identification of mines.

e. Warheads/Explosives and Rocket/Missile Propulsion

Goals and Timeframes

The warheads/explosives and rocket/missile propulsion subarea develops conventional warheads, explosives, and rocket/missile propellants for antiair, antisurface warfare. It includes efforts directed specifically toward advanced nonnuclear warhead concepts, advanced kill mechanisms employing multi-option warheads, new warhead materials, material process techniques, analytical design tools, advanced explosives, and adaptable, minimum smoke, insensitive propellants for rockets and missiles. Products include a demonstration for a focused reactive frag warhead in FY98, a FY00 demonstration of liquid propellants to combine the specific impulse and energy management of liquids with the field handling simplicity of solids; demonstration of more energetic explosive formulations, and a 90 percent reduction in the emissions from explosive processing and demilitarization by FY05.

Major Technical Challenges

One major challenge is to provide affordable performance optimized and matched to a broad range of targets and intercept conditions, while maintaining or reducing the weight and size of the warhead/rocket. Promising new materials, such as tantalum, molybdenum, and tungsten, may provide dramatic improvements in warhead lethality. The challenge is to understand the relationship between microstructure and plastic flow of tantalum, upset forging optimization, and parametric process variations in molybdenum and tungsten alloys. Higher performance requires more compact, higher energy density insensitive explosive formulations.

Specific challenges are:

- Design a warhead that produces multiple compact/controllable pattern fragments using detonation wave dynamic models, which predict fragment geometry, size, and velocity.
- Improve penetration of very short/long standoff shape charge and explosively formed penetrator warheads.
- Desensitize explosives by recrystallization to eliminate defects, by coating particles to reduce friction, or by reformulation.
- Synthesize new, more powerful explosive and propellant formulations using composites of new, less sensitive energetic constituents that produce environmentally "clean" exhaust products.
- Design fuel-efficient, lightweight, low-cost turbine engines and inducted/air-augmented rockets.

f. Weapon Lethality/Vulnerability

Goals and Timeframes

Weapon lethality/vulnerability (L/V) refers to the science of understanding the mechanisms by which a warhead or other ballistic mechanism can defeat a target. Vulnerability, a characteristic of a target, describes the effects of various damage mechanisms to the physical components of the target and the resulting dysfunction. Lethality, normally used from the perspective of the attacking weapon, includes the ability of the weapon to inflict the damage mechanisms upon the target, as well as the effects of those mechanisms (target vulnerability). The L/V subarea

addresses the tools, methods, databases, and supporting technologies (e.g., solid geometric modeling tools, modern coding environments, supportive hardware configurations) needed to assess the lethality and vulnerability of all U.S. weapon systems, including aspects of design, effectiveness, and survivability. Products include incorporation of tri-service blast models in FY99, and a 10-fold decrease in software preparation time in FY05.

Major Technical Challenges

The biggest challenge is to begin the complex task at the earliest possible stage in the weapon development or upgrade cycle, when inexpensive changes can lead to large increases in the survivability of crew and materiel and enhanced battlefield performance. To complicate matters, new penetrators (e.g., hypervelocity missiles, top attack systems, tactical ballistic missiles) must be modeled against an increasing list of sophisticated targets with new materials and novel armor designs.

Specific challenges are:

- Develop first-generation models to predict terminal effects on composite materials.
- Use statistical prediction methods to characterize fragment/debris clouds behind armors accounting for all fragment parameters (e.g., mass, speed, shape, spatial distribution).
- Extrapolate current L/V data to predict effects in new encounters with different materials and systems.
- Determine sensitivity of modern electrical subsystems and other components to ballistic blast and shock.
- Predict synergistic effects of concurrent damage mechanisms (fragment/penetrator and blast/shock) on structural components.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Conventional Weapons is shown in Table IV–18.

5. Linkages to Future Operational Capabilities

The influence of this technology area on TRADOC FOCs is summarized in Table IV–19.

Table IV–18. Technical Objectives for Conventional Weapons

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Fuzing—Safe and Arm	Incorporated neural nets, advanced sensors, and high-speed processors in GIF to increase system effectiveness by 39% Collect target signatures for electrostatic sensors (ESS)	Demonstrate standoff fuze against reactive/active armor Demonstrate miniaturized electronic fuzing for OICW bursting munitions	Demonstrate GIF aimable warhead capability Improve logistics by developing universal fuze components and subsystems
Guidance and Control	Conduct 40-km flight test of a multimode airframe technology missile against point targets Demonstrate 2,000% accuracy improvement of MLRS extended range free rocket	Demonstrate aimpoint selection via neural net Demonstrate strapdown MMW seeker that can acquire and track in a real-time laboratory test Develop solid-state/photonic components that reduce the cost of G&C systems by a factor of 3	Automate G&C software generation reducing acquisition cost by >10% Exploit multisensor target/scene simulation to reduce T&E costs by 30% Develop advanced hardware/software code sign techniques

Table IV–18. Technical Objectives for Conventional Weapons

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Guns—Conventional and Electric	Using ETC propulsion, launch a projectile at 2.5 km/s with muzzle energy of 7 megajoules (MJ) Demonstrate direct laser ignition of current propellant for artillery application Demonstrate antitank guided weapon performance against active protection system	Demonstrate a 30% increase in Abrams direct fire system accuracy with a 300% increase in probability of hit at 3 km Demonstrate OCSW prototype with a weight of <38 lbs Demonstrate 17 MJ kinetic energy at muzzle in a 120-mm XM291 cannon Demonstrate PGMM with first round target kill capability at 15 km	Demonstrate ETC tank gun technologies providing 25–30 MJ muzzle energy and 2.5 km/s muzzle velocity Demonstrate a 200% increase in hit probability at 4 km with 120-mm tank ammunition
Mines/Countermine	Demonstrate IMF acoustic sensor ability to autonomously detect seven target vehicles at >1 km Reproduce a vehicle signature to spoof off route mines up to 100 m away at speed up to 10 mph Ground penetrating radar (GPR) and IR detectors to find buried metallic and nonmetallic mines	Using robotic/remote controlled demolition devices, demonstrate demining ability with a 2 to 4 times improvement in cost and speed Apply multispectral imaging, GPR, and chemical/nuclear sensing in a vehicle-mounted detector to find buried, metallic, and nonmetallic mines	Utilize high-clutter targeting algorithm and high-speed processors to reconnaissance a minefield with high rate of search (50 square miles per hour) Demonstrate rapid clearing and 100% detection of mines
Warheads/Explosives and Rocket/Missile Propulsion	Demonstrate a long standoff anti-armor weapon Demonstrate a tactical air-breathing missile with a three- to four-fold increase in range Demonstrate low signature gel motor	Flight test a 35–40 kg compact kinetic energy missile matching LOSAT lethality Demonstrate a tactical subprojectile for the KE precursor warhead that meets aerodynamic and terminal requirements Use recrystallization and coatings to produce higher performance, but less sensitive deformable explosives Demonstrate warhead for active protection system (APS) to defeat full spectrum of threats	Reduces emissions from explosives production processing and demilling by 90% Double rocket payload/range without changing weight or volume Extended propulsion systems shelf life to more than 25 years Double warhead performance or cut warhead size in half
Weapon Lethality/Vulnerability	Develop first-generation models to predict and analyze penetration of emerging composite materials Develop model for stochastic analysis of fragment effects Upgrade L/V models to enhance wargame fidelity of the DISN	Develop and validate methodology to predict penetration by hypervelocity (400–1,400 m/s) weapons Improve body-to-body impact models for tactical ballistic missile targets Demonstrate first-order shock propagation model for high-explosive blast loading	Decrease software preparation time by a factor of 5; improve fidelity by a factor of 2; reduce life-cycle costs of conventional weapons by a factor of 2 Incorporate large-scale hypervelocity penetration mechanics of geological and layered structural materials Develop fire/thermal and toxic fume transport model

Table IV–19. Conventional Weapons Linkages to Future Operational Capabilities

Technology Subarea	Integrated and Branch/Functional Unique Future Operational Capabilities
Fuzing—Safe and Arm	TR 97–040 Firepower Lethality TR 97–043 Survivability—Materiel TR 97–044 Survivability—Personnel
Guidance and Control	TR 97–040 Firepower Lethality
Guns—Conventional and Electric	TR 97–040 Firepower Lethality TR 97–042 Firepower Nonlethal
Mines/Countermine	TR 97–041 Operations in an Unexploded Ordnance/Mine Threat Environment
Warheads/Explosives and Rocket/Missile Propulsion	TR 97–040 Firepower Lethality
Weapon Lethality/ Vulnerability	TR 97–040 Firepower Lethality TR 97–043 Survivability—Materiel TR 97–044 Survivability—Personnel

J. ELECTRON DEVICES

1. Scope

The Army program in electron devices generates the cutting-edge components essential for a vital advantage over complete dependence on widely available commercial electronics. This technology area capitalizes on basic research in the forefront of science (Chapter V), and advances it to the exploratory development subsystem level. It includes focused research, development, and design of electronic materials; nanoelectronic devices (including digital, analog, microwave, and optoelectronic sensors and circuits); electronic modules, assemblies, and subsystems; and the required portable power sources. Electron devices technology comprises four major subareas: EO, MMW components, nanoelectronics, and portable power sources.

2. Rationale

Supremacy in electron devices is crucial to supremacy on the digitized battlefield. A superior, versatile, innovative program in electron device S&T is essential to the broad Army vision of (1) decisive force multiplication with a minimum number of platforms and personnel, (2) avoidance of potentially disastrous technological surprise on the battlefield, and (3) complete situational awareness on the battlefield. Power on the battlefield is a cornerstone to battlefield effectiveness. The technology supports the Army's five modernization objectives, STOs, and ATDs. Requirements of Army systems such as EW, radar, and C^4I translate into component requirements, which may include performance, weight, size, radiation hardness, interoperability, cooling, power consumption, maintainability, and survivability. This technology area represents over 40 percent of the procurement cost of many military systems. Military purchases of semiconductor electronics have increased annually. Semiconductor electronics were one of very few areas to experience significant growth. Fielding of weapons systems that meet present requirements, that can be upgraded to meet future requirements, and that have affordable life-cycle costs will demand exploitation of commercial electronics whenever possible, plus development of the special technologies here for Army systems that need unique capabilities.

3. Technology Subareas

a. Electro-Optics

Goals and Timeframes

The objective of the EO subarea is to develop critical EO components such as lasers, focal plane arrays (FPAs), amplifiers, detectors, photonic devices, fiber optics, and low power displays for application in Army tactical and strategic systems.

Near-term goals include support of development of high-resolution, full-color displays for land warrior head-mounted vision systems, realization of multispectral FPAs with adjacent LADAR, fiber-optic distributed sensors, and on-chip, optical interconnects.

Mid-term goals include development of smart multicolor staring FPAs for robust seekers and acquisition sights, integrated optoelectronic staring laser radar (LADAR), nonlinear optical devices for sensor protection and improved phosphors and materials for miniature flat panel displays.

Long-term goals include development of integrated multidomain (LADAR and multispectral FPA) smart sensor elements, miniature hybrid optical image processors, real-time smart vision systems, portable high-power tunable laser sources, and new display technologies. DARPA is currently supporting the Army's interest in uncooled FPA technology, miniaturized, high-resolution flat-panel displays and optical interconnects. (This support is noted by the symbol [*D] in Table IV–20.)

Major Technical Challenges

Technical challenges include the development of more reliable, higher efficiency, higher

frequency, longer wavelength solid-state lasers; optical signal processors; cost-effective modules for information systems and IRFPAs; receive-architecture for optically fed phased-array radar; new low-power flat-panel display.

Specific technical challenges include:

- Monolithic integration of optoelectronic devices on silicon.
- Design and development of optical interconnects.
- Growth of novel thin film materials for uncooled detectors.
- High efficiency phosphors.
- Photolithography and/or electrical circuitry manufacturing issues for 2,000 lines/inch displays.
- Integration of smart functions onto FPAs.
- Long-lived UV laser diode operation at room temperature.
- Fusion of multispectral images.
- Large area multicolor FPAs.
- Solid-state tunable direct lasing in the UV.
- Development of portable, tunable solid-state IR lasers.
- Development of superconducting components and cryogenic antennas.
- Redesign of the I^2 tube with no undue impact on tube lifetime.
- Integration of reflection modulators and FPAs.
- Processing of data from LADAR and FPA.

b. Millimeter-Wave Components

Goals and Timeframes

Near-term goals are to insert affordable monolithic microwave integrated circuits (MMIC) into low-cost expendable decoys, low-cost moving target indicator (MTI) radar, and smart munition seekers; to develop mature and affordable MMW integrated circuit (IC) technology for next-generation, target acquisition systems and MMW satellite communications.

Mid-term goals are to continue cost reduction and increase the density and functional capabilities of MMIC assemblies and packages, extend microwave power module (MPM) technology to the MMW frequency regime, and provide common, secure, jamproof, affordable wireless communications, and battlefield IFF.

Long-term goals are to achieve unprecedented levels of integration of diverse RF sensors into common apertures to reduce system size and weight by an order of magnitude while meeting military cost, performance, reliability, and radiation hardness requirements. In brief, the overall goal is to own the battlefield electromagnetic spectrum.

Major Technical Challenges

Among the technical challenges in millimeter-wave components are the achievement of high power, high efficiency, large dynamic range, wide bandwidth, flexible manufacturing modeling and simulation, to enable first-pass success of components, modules, and arrays, and process integration necessary for high-yield, low-cost multifunctional solid-state devices and vacuum tubes. All these attributes must be provided at an affordable cost.

c. Nanoelectronics

Goals and Timeframes

Near-term goals include development of scalable manufacturing processes and cluster and lithography tools for flexible fabrication of integrated compound semiconductor devices, advanced process synthesis technology, novel devices for very high throughput digital signal processors, integration of electronic combat and combat-support functions, wide-bandgap semiconductor devices for high-temperature electronics, pulse power electronics, nonvolatile memories, and microscale electromechanical components.

Mid-term goals include development of lithography and fabrication capabilities for

low-volume, affordable integrated microwave, digital, and optical processors.

Long-term goals include flexible and affordable fabrication capabilities for concept demonstrations of fully integrated, nanometer feature size, ultra-dense circuits for revolutionary warfighting sensor and information systems capabilities.

Major Technical Challenges

Among the technical challenges are creating new wide-bandgap semiconductor devices for high-temperature electronics and for low-leakage, high-breakdown, highly linear power devices; high-quality, radiation-hardened devices of diverse technologies; mixed-signal operation of nanoelectronics with on-chip millimeter-wave and EO components; very low power circuits, and affordable custom nanoscale semiconductor processing for unique military applications-specific circuits. An overall major challenge is the development of high-performance, low-power electronic systems for a substantial reduction in battery requirements and associated weight and size penalties.

d. Portable Power Sources

Goals and Timeframes

The objectives of this program are to lighten the soldier's burden, provide critical steady- and pulse-power components, and reduce logistical and disposal costs. This can be done by applying chemistry, energy conversion, electronics, and signature suppression to improve existing power systems and to enable the development of newer, more advanced batteries, fuel cells, capacitors, and electromechanical (including engines and permanent magnet alternators) components and systems.

The general goal is to develop small, lightweight, low-cost, environmentally compatible power sources with high power and energy densities for communications, target acquisition, combat service support applications, miniaturized displays, and microclimate cooling for the Future Soldier System.

Specific near-term goals are:

- Next generation, high energy (150–225 watt hour/kilogram (Wh/kg)) primary lithium (Li) batteries for man-portable equipment.
- Lighter weight, higher energy density (80 Wh/kg) metal hydride or Li-ion rechargeables.
- Improved spin-stable reserve batteries.
- Develop low temperature (–30°C electrolyte for Li-ion batteries.
- New electrolytes for low-cost electrochemical capacitors.
- Man-portable 100 to 300 watt hydrogen-fueled fuel cells for soldier systems .
- Man-portable (40 lb/kW), signature suppressed 3,000-W-engine-driven generator set. The engine will have a brake-specific fuel consumption (BSFC) of 0.52 and thermal efficiency of 25 percent and will be capable of starting and operating on DF–2/JP–8 fuels.
- DARPA sponsored thermophotovoltaic (TPV) power source.

Specific mid-term goals are:

- Higher energy density (>350 Wh/kg) Li primary batteries.
- Improved energy (>100 Wh/kg) rechargeable batteries.
- Low-cost electrochemical capacitors for electric vehicles.
- Fuel cell stacks that operate on liquid fuels.
- Demonstration/validation of signature-suppressed, electronically controlled, man-portable/man-handleable 0.5–3.0 kW-engine-driven generator sets that provide power on the move, enhance total asset visibility and combat services support (CSS) operations and are

compatible with emerging C^4I and weapons systems.

- Continue demonstration of DARPA sponsored thermovoltaic power source.

Specific long-term goals are:

- Rechargeable Li/polymer batteries with energy densities >150 Wh/kg, low cost, and improved safety.
- New pouch primary combat battery (250 Wh/kg) in flexible conformal packaging.
- Practical silent TPV power sources.
- 1 to 50 kW transportable fuel cells.
- Active batteries with very long shelf life for smart munitions.
- Batt/cap devices capable of full charge/discharge in minutes, with energy densities >200 Wh/kg.
- Portable 5,000–watt diesel-engine-driven generator set compatible with emerging C^4I and weapons systems.
- Demonstration of dual-use electromechanical (power generation, transmission, distribution, or utilization) technologies and equipment (0.5–1100 kW) that reduce system size/weight and visual/audible IR signatures, improve system reliability, minimize operation and support costs, and improve the deployability, tactical mobility, and effectiveness of a CONUS-based fighting force.

Major Technical Challenges

Nonflammable, high-conductivity electrolytes, more energetic cathode materials, and lower-cost manufacturing methods for Li batteries, compact hydrogen generators, improved fabrication methods for metal hydride cells, higher voltage and more capacitive electrode materials for electrochemical capacitors, improved polymer exchange membranes and electrocatalysts for fuel cells, spectrally matched emitters and photocells for TPV systems, and higher efficiency combustion of and greater reliability/life for man-portable/man-handleable engine driven generator sets.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Electron Devices is shown in Table IV–20. (The symbol [*D] denotes DARPA supported programs.)

Table IV–20. Technical Objectives for Electron Devices

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Electro-Optics (Photonic Devices)	Order of magnitude improvement in spatial light modulator (SLM) dynamic range and speed Vertical cavity surface emitting laser (VCSEL) array integrated with Si-driver chip for optical interconnects Photonic and electronic devices integrated on the same chip Image-forming light modulator in a hybrid (digital-optical) ATR Free-space reflection modulators & modulator arrays Integrate loss-less splitter & phase shifter for optically controlled phase array antennas On-chip, optical interconnects High-resolution adaptive system for aberration correction	Integrated optoelectronic staring laser radar Integrated optical module for optical control of microwave phased array antenna Order of magnitude faster hybrid (digital-optical) image processor with reduced size and power requirements Matured technology base in the synthesis and characterization of electro-optical materials Modulation of RF signals with laser diodes Optoelectronic computing [*D] Intelligent imaging systems on silicon	Massively parallel architectures Miniaturized hybrid (digital-optical) general purpose optical image processor Optoelectronic neural nets Real-time smart vision systems

Table IV–20. Technical Objectives for Electron Devices (continued)

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Electro-Optics (Fiber Optic Technology)	Multiplexed fiber-optic sensor Integrated semiconductor & polymeric optoelectronic components for fiber optic gyros Environmentally stable fiber optic dispensers Manufacturing process for interferometric fiber-optic gyros (IFOG)	Distributed fiber-optic sensor with 10 times as many acoustic channels Miniature integrated chip components Highly reliable miniature (3-axis) IFOG Efficient coupling techniques for miniature components Fiber-optic strain-sensing techniques Integrated photonic subsystems	Highly reliable international measurement unit (IMU) on-chip resonant fiber-optic gyro Demonstration of fiber-optic gyro Demonstration of small, ultra long-range, fiber-optic datalinks
Electro-Optics (Smart Multispectral Detectors and Sources)	Large-area staring long wave infrared (LWIR) detectors Thin-film uncooled ferroelectric IR detector w/projected noise equivalent delta temperature (NEDT) <0.01°C [*D] Image intensification (I^2) devices with an improved signal-to-noise ratio and better resolution Increased power/tunability of IR sources Two-color FPA demonstration of either mercury, cadmium telluride (MCT) or quantum well infrared photodiode (QWIP) with adjacent breadboard LADAR Efficient visible wavelength conversion Nonlinear optical material research for sensor protection	Efficient laser sources in the UV for CB detection Nonlinear optical devices for sensor protection Uncooled FPA with NEDT <0.01°C for F/1 system [*D] Efficient laser source at 3–5 μm Eye-safe micro solid-state lasers Smart multicolor FPA (QWIP or MCT) demonstration Multidomain smart sensor demonstration Metallo-organic molecular beam epitaxy (MOMBE) producible smart multicolor FPA with image processing functions Two-color uncooled camera [*D] Large, 3-color hyperspectral array for an overhead (space) sensor	Monolithic multifunction, multispectral (including LADAR) smart FPA Broadband, low-cost, low-loss, IR/ visible, passive sensor protection Portable, high-power, tunable (UV to far IR (FIR)) laser source for multiple applications Long-life, UV laser diode operation at room temperature
Electro-Optics (Smart High-Resolution Displays)	High-resolution, full-color flat-panel displays for tactical environments 1000 line/inch miniature flat panel displays for helmet-mounted displays (HMDs) or other applications [*D]	Miniature high-resolution displays for telepresence and virtual environment applications [*D] 2000 line/inch miniature flat panel displays for HMDs or other applications [*D] Reduced power HMDs	Real-time holographic (3D) displays
Electro-Optics (Millimeter-Wave, IR Sensor Processors)	Prototype superconductor antennas Integrated IR sensor and processor Coupled quantum well (QW) research of optoelectronic components	LWIR forward-looking infrared (FLIR) based on MCT, superlattices, and QWIPs Fusion of multiple wideband sensors 2000 × 1000 quantum-well staring arrays	Advanced device technology in support of Far IR goggles 2D array of superlattice long-wave detectors

Table IV–20. Technical Objectives for Electron Devices (continued)

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Millimeter-Wave Components analog monolithic microwave integrated circuit (MMIC) devices	Continuous increases in single radar-type function (amplifiers, oscillators, mixers, switches) chips in the 1 to 140 gigahertz (GHz) range Cost reduction of chips	Microwave/digital ICs Microwave/optical ICs Vehicular radar MMW wireless communications High-density 3D packaging High-power vacuum devices	Full integration of MIMICs with digital and optoelectronic devices in the 100 to 200 GHz range
Millimeter-Wave Components (High Power and Sub MMW Sources)	Demo Ka-band power amplifier for missile seekers Broadband subMMW amps for advanced weapon systems	High efficiency MMW power modules Compact magnet structures for subMMW sources	Extension of sources to terahertz and infrared spectral regions
Millimeter-Wave Components (Acoustic-Wave Devices)	Family of ultra-stable low noise frequency sources High-performance frequency channelizer	Miniature atomic frequency standards Fully adaptive bandpass/bandstop filters CB sensors Vibration-resistant oscillators Miniaturized filters/resonators Low cost ID tags Analog/digital hybrid processors Nonreciprocal acoustic components	Multicolor IR sensors, accelerometers Thin-film and other monolithic resonators/acoustic components integrated with MMIC transceivers Automated microcomputer compensation and laser-aided fabrication error correction Miniaturized frequency channelizer
Nanoelectronics (Compound Semiconductor Manufacturing)	Advancement of MOMBE and metallo-organic chemical vapor deposition (MOCVD) single-wafer deposition technology Development of silicon carbide (SiC) process technology for high temperature electronics and power devices Ferroelectric film development for nonvolatile memory applications	Development of reliable sources of indium phosphide (InP) wafers Heteroepitaxial growth of device-quality gallium arsenide (GaAs) on silicon (Si) Development of wide bandgap SiC devices for high temperature and high power applications Ferroelectric nonvolatile memories for digital battlefield applications	Development of gallium nitride (GaN) materials and devices Accelerometers
Nanoelectronics (Integrated Optics)	Process for growth and characterization of EO polymers Device functions in EO polymers Demonstrate limiting and thresholding operations in nonlinear materials	Process for growth and characterization of indium phosphide Integrated optics device functions in indium phosphide Selective technology insertion of integrated optics functions based on EO polymers	Technology insertion of selected integrated optics functions High speed digital (soliton) coupling and logic operation devices

Table IV–20. Technical Objectives for Electron Devices (continued)

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Nanoelectronics (Micromechanical Actuator-Sensors)	Micromachined structures and materials for miniature sensors and actuators Micro-acoustic sensors for target detection and CB sensing Miniature gyroscopes and accelerometers for inertial guidance	Miniature medical instruments for surgery Monolithically integrated miniature sensor/actuator microsystems Integrated sensor readout circuits for real-time information output	Embedded microsensors and actuators for automated missile guidance, structural failure prognosis, personal navigation, and medical diagnosis/treatment
Portable Power Sources	Low-cost primary Li battery, >150 Wh/kg Develop low temperature (–30°C) electrolyte for Lithium-ion batteries Improved energy density metal hydride or Li-ion rechargeable batteries, >80 Wh/kg High voltage electrolyte for low-cost electrochemical capacitor Man-portable hydrogen fuel cell stack Improved reserve batteries for GPS, high-spin munitions Lightweight, DF–2 fueled, 500 W TPV power source with 8% efficiency	Primary Li batteries with energy densities >300 Wh/kg Rechargeable batteries with energy densities >100 Wh/kg Low-cost high-energy electrochemical capacitors for vehicles Liquid-fueled fuel cell stacks Investigate validity of TPV technology for battlefield use and demonstrate improved efficiency (15%) using recommended upgrades	Rechargeable batteries with energy densities >250 Wh/kg New pouch primary battery (250 Wh/kg) Practical, thermophotovoltaic charger using logistic fuels Advanced polymer or solid-oxide fuel cell with up to 50 kW power Batt/cap devices with charge/discharge in minutes, >200 Wh/kg
Electromechanical Technologies	Man-portable, signature suppressed 3000 W (40 lb/kW) engine driven generator set capable of burning JP–8/DF–2	Demonstration and validation (DEM/VAL) signature suppressed, electronically controlled man-portable/man-handleable 500–3,000 W engine driven generator sets	Man-portable, signature suppressed, electronically controlled 5,000 W (70 lb/kW) engine driven generator set capable of burning JP–8/DF–2 Dual use electromechanical technologies and equipment (0.5 to 1.1 kW) which will reduce system size/weight and signatures, improve system reliability and tactical mobility, and enhance the effectiveness of CONUS-based forces

5. Linkages to Future Operational Capabilities

The influence of this technology area on TRADOC FOCs is summarized in Table IV–21.

Table IV–21. Electron Devices Linkages to Future Operational Capabilities

Technology Subarea	Integrated and Branch/Functional Unique Future Operational Capabilities
Electro-Optics (Photonic Devices)	TR 97–001 Command and Control TR 97–006 Combat Identification TR 97–007 Battlefield Information Passage TR 97–010 Tactical Communications TR 97–011 Information Services TR 97–013 Network Management TR 97–016 Information Analysis TR 97–020 Information Collection, Dissemination, and Analysis TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–027 Navigation TR 97–045 Camouflage, Concealment, and Deception TR 97–053 Embedded Training and Soldier–Machine Interface TR 97–054 Virtual Reality TR 97–055 Live, Virtual, and Constructive Simulation Technologies
Electro-Optics (Fiber Optic Technology)	TR 97–006 Combat Identification TR 97–010 Tactical Communications TR 97–017 Information Display TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–052 Training Aids, Devices, Simulators, and Simulations Fidelity Requirements TR 97–054 Virtual Reality
Electro-Optics (Smart Multispectral Detectors and Sources)	TR 97–001 Command and Control TR 97–006 Combat Identification TR 97–007 Battlefield Information Passage TR 97–010 Tactical Communications TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–043 Survivability—Materiel TR 97–044 Survivability—Personnel TR 97–045 Camouflage, Concealment, and Deception TR 97–052 Training Aids, Devices, Simulators, and Simulations Fidelity Requirements TR 97–057 Modeling and Simulation
Electro-Optics (Smart High Resolution Displays)	TR 97–006 Combat Identification TR 97–007 Battlefield Information Passage TR 97–016 Information Analysis TR 97–017 Information Display TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–054 Virtual Reality TR 97–055 Live, Virtual, and Constructive Simulation Technologies TR 97–056 Synthetic Environment TR 97–057 Modeling and Simulation
Electro-Optics (Millimeter Wave, IR Sensor Processors)	TR 97–019 Command and Control Warfare TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–045 Camouflage, Concealment, and Deception TR 97–053 Embedded Training and Soldier–Machine Interface TR 97–054 Virtual Reality TR 97–057 Modeling and Simulation

Table IV–21. Electron Devices Linkages to Future Operational Capabilities (continued)

Technology Subarea	Integrated and Branch/Functional Unique Future Operational Capabilities
Millimeter-Wave Components (Analog MIMIC Devices)	TR 97–001 Command and Control TR 97–006 Combat Identification TR 97–010 Tactical Communications TR 97–011 Information Services TR 97–013 Network Management TR 97–017 Information Display TR 97–019 Command and Control Warfare TR 97–020 Information Collection, Dissemination, and Analysis TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–045 Camouflage, Concealment, and Deception TR 97–057 Modeling and Simulation
Millimeter-Wave Components (High Power Terahertz Sources)	TR 97–006 Combat Identification TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–035 Power Source and Accessories TR 97–045 Camouflage, Concealment, and Deception TR 97–057 Modeling and Simulation
Millimeter-Wave Components (Acoustic Wave Devices)	TR 97–006 Combat Identification TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–045 Camouflage, Concealment, and Deception TR 97–057 Modeling and Simulation
Nanoelectronics (Compound Semiconductor Manufacturing)	TR 97–006 Combat Identification TR 97–010 Tactical Communications TR 97–011 Information Services TR 97–017 Information Display TR 97–019 Command and Control Warfare TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–035 Power Source and Accessories TR 97–057 Modeling and Simulation
Nanoelectronics (Integrated Optics)	TR 97–006 Combat Identification TR 97–017 Information Display TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–045 Camouflage, Concealment, and Deception TR 97–052 Training Aids, Devices, Simulators, and Simulations Fidelity Requirements TR 97–057 Modeling and Simulation
Nanoelectronics (Micromechanical Actuator–Sensors)	TR 97–006 Combat Identification TR 97–017 Information Display TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–045 Camouflage, Concealment, and Deception TR 97–052 Training Aids, Devices, Simulators, and Simulations Fidelity Requirements TR 97–057 Modeling and Simulation

Table IV–21. Electron Devices Linkages to Future Operational Capabilities (continued)

Technology Subarea	Integrated and Branch/Functional Unique Future Operational Capabilities
Portable Power Sources	TR 97–001 Command and Control TR 97–004 Tactical Operation Center Command Post TR 97–007 Battlefield Information Passage TR 97–010 Tactical Communications TR 97–019 Command and Control Warfare TR 97–020 Information Collection, Dissemination, and Analysis TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–028 Unmanned Terrain Domination TR 97–035 Power Source and Accessories TR 97–036 Nonprimary Power Sources Combat Vehicles/Support Systems TR 97–038 Casualty Care, Patient Treatment, and Area Support TR 97–052 Training Aids, Devices, Simulators, and Simulations Fidelity Requirements MD 97–001 Patient Evacuation MD 97–004 Combat Heath Support in a Nuclear, Biological, and Chemical Environment
Electromechanical Technologies	TR 97–010 Tactical Communications TR 97–019 Command and Control Warfare TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–035 Power Source and Accessories TR 97–036 Nonprimary Power Sources Combat Vehicles/Support Systems TR 97–045 Camouflage, Concealment, and Deception TR 97–052 Training Aids, Devices, Simulators, and Simulations Fidelity Requirements

K. ELECTRONIC WARFARE/DIRECTED ENERGY WEAPONS

1. Scope

Electronic warfare (EW) includes any military action involving the use of electromagnetic and directed energy to control the electromagnetic spectrum or attack an enemy. EW comprises three major subdivisions:

- *Electronic attack* (EA)—Use of electromagnetic or directed energy to attack personnel, facilities, or equipment with the intent of degrading, neutralizing, or destroying enemy combat capability.
- *Electronic support* (ES)—Actions taken by, or under direct control of, an operational commander to search for, intercept, identify, and locate sources of radiated electromagnetic energy for immediate threat recognition in support of EW operations and other tactical actions such as threat avoidance, homing, and targeting.
- *Electronic protection*—actions taken to protect personnel, facilities, or equipment for any effects of friendly or enemy employment of electronic warfare that degrade, neutralize, or destroy friendly combat capability.

EW and directed warfare are leading technologies for solving Army problems in scenarios where nonlethal (i.e., no permanent injury) or less than lethal (i.e., could suffer serious injury) force is required.

Figure IV–8 illustrates directed energy weapons (DEW) and jamming applications on the battlefield. Figure IV–9 depicts the electronic power relationships between EW jammers and RF–DEWs.

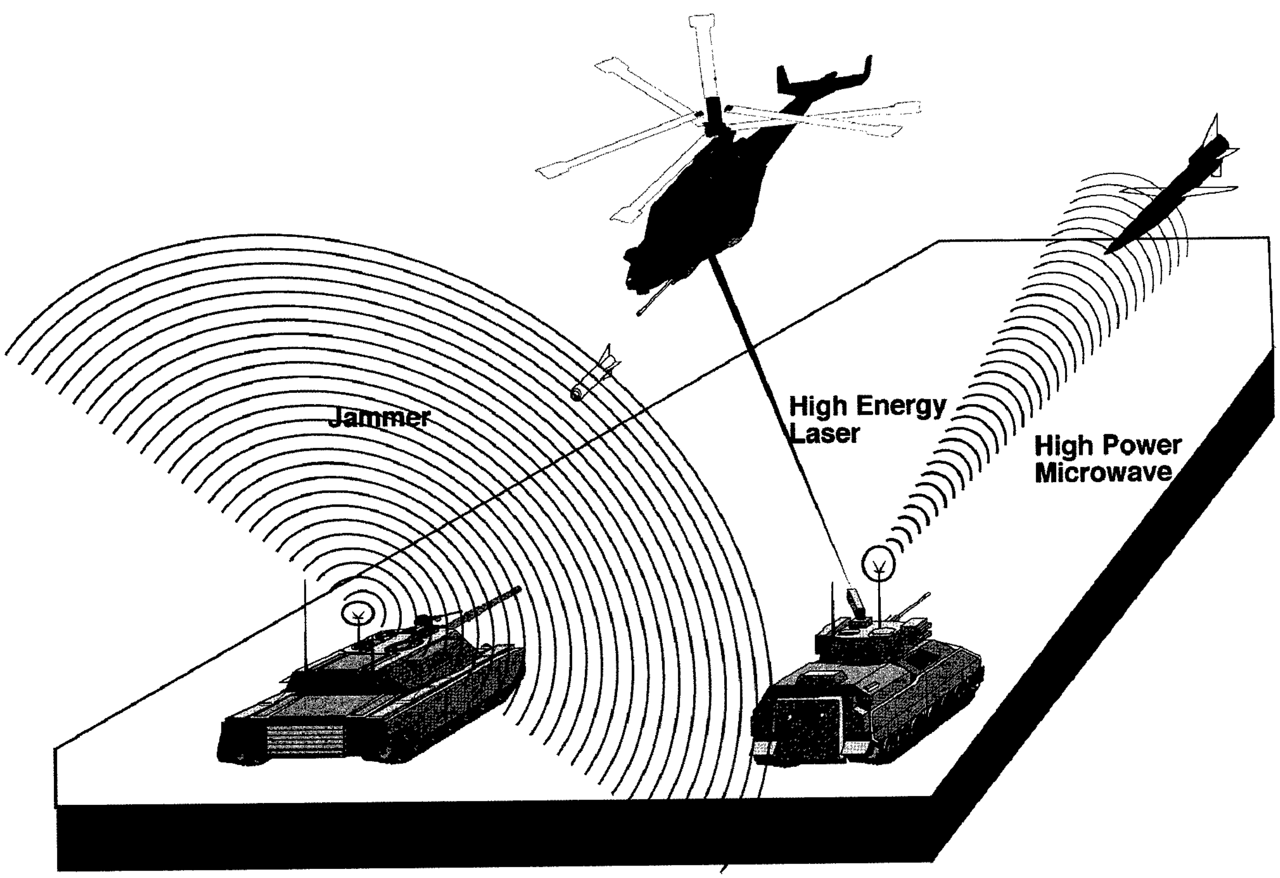


Figure IV–8. Battlefield Applications of DEW and Jamming

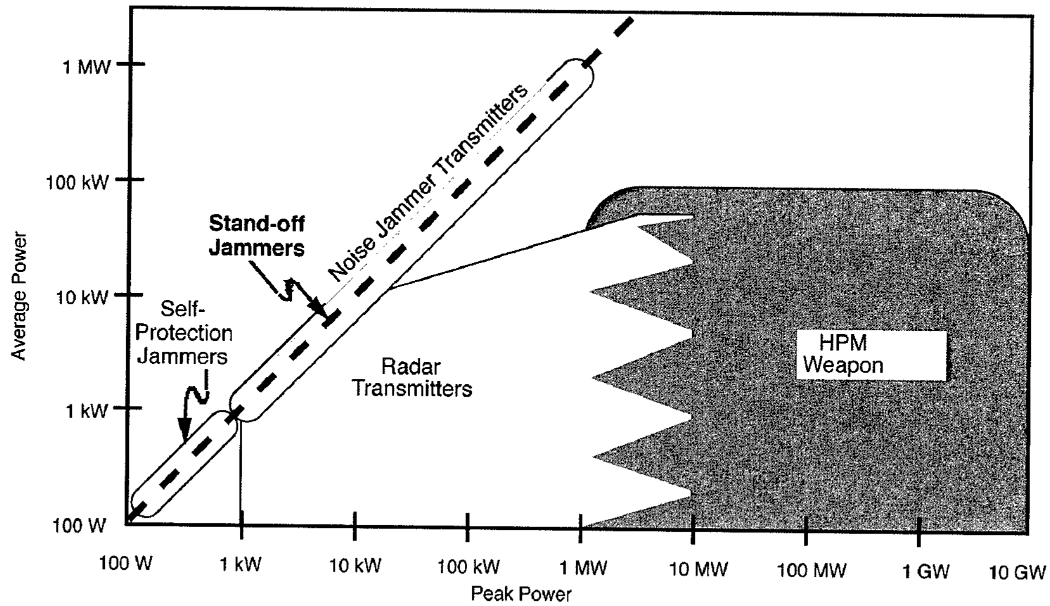


Figure IV–9. Comparison of EW Jammer and RF–DEW Power Relationship

2. Rationale

As the roles, missions, and capabilities of today's Army evolve into the 21st century, so then does the role of EW. Dominance of the electromagnetic spectrum based on the ability to use and deny its use by others at will is dependent on industry, academia, the other services, and a robust program to sustain the Army's unique requirements on the electronic battlefield. As threat systems become more complex, the need to develop EW systems that can respond to changing environments is critical to superior battlefield surveillance and survivability. Technology to collect, recognize, and process complex wave forms and provide effective jamming are essential. Knowledge-based systems using artificial intelligence and adaptive parallel distributed processing can provide "smart" software control to maintain an edge on a dense signal battlefield.

3. Technology Subareas

a. Electronic Attack

Goals and Timeframes

Develop the technologies that provide the capability to intercept and bring under EA advanced communications signals being used by adversarial C^2 networks on the digital battlefield. Through EA strategies demonstrated with prototype hardware and software, these digital communications signals will be disrupted, denied, or modified to render the communications system ineffective and unreliable to the threat command and control function. Near-term goals are to demonstrate electronic attack against a set of digital formats being implemented in commercial communications systems and data transmission systems. Mid-term goals are to demonstrate the ability to disrupt other commercial communication networks and wide bandwidth communications. Long-term goals include the ability to surgically attack specific users within a nonobtrusive means while maintaining the overall integrity of the targeted communications network.

Development of sensor and countermeasure technologies is a complex chess game of trying to outplay your opponent, betting that your defensive systems can outmatch his offensive capabilities. Advanced technology and tactics are the last line of defense where a time span of 2 seconds or less can mean the difference between winning or losing. Technology goals include development of multifunctional/multispectral IR countermeas-

ures, radar and laser warning, and countermeasures that can provide both self- and area-protection of air and ground platforms, as well as targeting and real-time situational awareness at the fighting station(s). Near-term goals include demonstration of a beam coupler for the DARPA laser/antitank infrared countermeasures (IRCM) point/tracker, the evaluation of IRCM techniques for top attack threats for ground vehicles, and the demonstration of an RF sensor and ECM modulator with the capability to locate, deceive, and jam monopulse and phased array radars from ultra high frequency (UHF) through millimeter wavebands. Mid-term goals include development of countermeasures for advanced EO/IR missiles using imaging seekers, and the continued development of advanced RF countermeasures with low-cost fingerprinting for signal sorting, jamming, targeting, and combat identification. Long-term goals include initiatives to develop integrated RF/IR/laser sensors and countermeasures against advanced EO/IR surface-to-air missiles and horizontal/top attack smart munitions.

Major Technical Challenges

The increasing use of common carrier commercial communications networks by potential adversaries presents the major technical challenge. We must be able to separate the threat-relevant communications from the purely commercial traffic and perform effective EW without disrupting the entire network. These targeted communication systems are characterized as adaptive sophisticated digital networks and modulation schemes that employ various layers of protocol and user protection.

Technology challenges also include development of uncooled, low false alarm rate detectors with <1 degree angle of attack (AOA) accuracy, development of multicolor IR focal plane array (FPA) (Navy/Air Force program), missile detection algorithms, and development of more efficient, low-cost, temperature stable IR/UV filters. The development of advanced high-speed wideband digital receivers using a GaAs microscan design approach, and the development of high power ultra-wideband digital RF memory (DRFM) jamming modulators and transmitter sources from A through M bands using MPM, MMIC, and fiber-optic remoting of sensors and transmitters. Precision AOA for situational awareness and targeting.

b. Electronic Support

Goals and Timeframes

As modern communication systems evolve, the overall goal is to develop the technology required to provide an electronic support/electronic attack (ES/EA) capability to intercept and counter these new priority threats and to provide the battlefield commander with the tactical intelligence products that contribute to his ability to accomplish his mission. Near-term goals include the downsizing of existing bulky components to provide a rapidly deployable capability and the conversion from special-purpose processors and software to a general-purpose suite. The intent is also to provide the ability to specifically tailor and reprogram these systems quickly, locally or remotely, to meet the current and changing threat. Mid-term goals include development of signal processing techniques that provide effective ES against common carrier, multiple access commercial communications in order to identify, locate, and exploit threat users. Another goal is the development of the tools required to display increasingly complex data to the soldier operators in support of the IEW mission. The long-term goal includes the continued development of adaptive sensor technologies that can perform the ES mission as the use of increasingly more complex communication systems continues to evolve.

Major Technical Challenges

The increasing use of common carrier commercial communications networks by potential adversaries presents the major technical challenge. This implies the need for advanced front-end receiver architectures and signal processing techniques capable of providing ES mission functions against increasingly complex sig-

nal modulation methods and structures coupled to higher data rates and user protection schemes.

c. RF-Directed Energy Weapons

DEW includes laser, high power radio frequency (HPRF), and particle beam technologies. (HPRF technology is frequently called high power microwave (HPM) or RF directed energy.)

Electronic equipment can be defeated or impaired by irradiation from directed energy (DE) sources. Degradation can range from temporary "upsets" in electronics subsystems, permanent circuit deterioration, or permanent destruction due to burnout or electrical overload. As modern systems and their components become ever more reliant on sophisticated electronics, they also become more vulnerable to DE radiation. The Army's DE program priority is to assess potential vulnerability of U.S. systems to unintentional irradiation "fratricide" by our DE-capable systems as well as intentional irradiation by enemy DE systems. DE hardening technology is being developed to mitigate both of these threats. In addition, the Army S&T program provides sources and components to support the susceptibility assessment program, support possible future applications, and avoid technological surprise from an adversary's breakthrough.

Goals and Timeframes

Near-term goals for RF–DE weapons are (1) the development of new HPRF source concepts, such as the interference modulation HPM source concept and frequency agile, broadband klystrons for use in susceptibility testing and in field tests, and (2) RF–DE weapons hardening for MMIC circuits used in Army systems. A mid-term goal is the development of high-gain, broadband antennas. Long-term goals include development of silicon carbide hardening devices and use of chaos theory research results to achieve greater control of RF–DE weapon sources.

Major Technical Challenges

High power RF generators need to be smaller, lighter, and more fuel efficient. Projected targets require intensive susceptibility studies to determine the best attack methods. These technical challenges will be overcome by concentrating technology development efforts on improving modulators, RF sources, and antennas. Improvements to reduce size, weight, and power requirements must also be accomplished by enhancements to radiation beam control.

d. Lasers

Compact, high efficiency lasers are critical for electro-optical countermeasures (EOCM), IRCM, and DEW applications. The maturation of diode pumped lasers, nonlinear frequency conversion techniques, and advanced laser design have made it feasible to incorporate these devices into tactical vehicles and aircraft for self-protection and missile defense. The challenge is to demonstrate the required power levels in a compact package for Army applications and to scale the power to higher levels for future needs.

Goals and Timeframes

In FY96, a DARPA / tri-service program demonstrated compact solid-state mid-IR lasers that would meet Army ATD requirements. That program increased available power by an order of magnitude. As a result, optically and electronically pumped solid-state lasers for IRCM applications that will transition to EMD by FY00 should have significantly lower cost, size, and power consumption. These lasers are being developed under a management agreement between DARPA and the services. Other recent accomplishments include the 1996 demonstration of technology for an active tracker system used in IRCM/EOCM applications to provide precision pointing and atmospheric compensation, the FY97 breadboard demonstration of a DARPA/Army 10 joule/100 hertz (Hz) diode pumped laser (DAPKL) and the development of a wide pulse IRCM laser with Lincoln Laboratories.

Major Technical Challenges

The major challenge to scaling the mid-infrared lasers is the development of an optical parametric oscillator (OPO) that can handle the

higher average powers without damage. Other issues include packaging lasers for use on aircraft and cost reduction of laser diode arrays. A longer term challenge will be the scaling of compact solid-state lasers to higher powers for standoff directed energy applications.

Specific challenges include:

- Increasing the power/weight ratio by threefold for sensor countermeasure systems.
- Scaling the power output of solid-state lasers by 10X to 20X in a compact package.
- Developing direct diode laser sources with wavelengths from blue/UV to mid IR.
- Reducing the cost of laser diode arrays to less than $1/peak watt.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Electronic Warfare/Directed Energy Weapons is shown in Table IV–22.

5. Linkages to Future Operational Capabilities

The influence of this technology area on TRADOC FOCs is summarized in Table IV–23.

Table IV–22. Technical Objectives for Electronic Warfare/Directed Energy Weapons

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Electronic Attack (Signal Processing)	33% reduction in processing time: power efficiency increase 33%, size reduction 25%	Increase number of signals tracked by 200%	50% increase in processing speed and computations per second
Electronic Support (Receivers)	Improved dynamic range 20%	Size reduction 50%	8:1 reduction in size and power
Electronic Attack (Antennas)	Improved broadband HF/VHF passive antenna efficiency by 10% E–J band precision AOA, polarization insensitive	Improved efficiency >30%, size reduction 90% A–K band High gain, high power ground band antennas	40% improvement in HTSC material operating conditions Integrated A–M band, laser warning, EO/IR FPA
Electronic Attack (Radar Jamming Techniques and Modulators)	Jam monopulse and phased array, DRFM 200 MHz BW	Phase O array and spared spectrum radars DRFM 3-GHz bandwidth	Impulse and bistatic radars DRFM 10-GHz bandwidth
Electronic Attack (Fuze/Smart Munition Jamming)	Precision DRFM, 50 picosec in 10-Hz steps	Precision DRFM, 5 picosec on 1-Hz steps	Precision DRFM, 1 picosec in sub Hz, 10-GHz bandwidth
Electronic Attack (Fiber Optic Cable for IRCM/Laser Warning)	Mid IR <1 db/m	Mid IR, visible <1 db/m	Mid-long IR, visible <0.5 db/m
Electronic Attack (IR Missile Jamming)	Mid IR CONSCAN	Mid IR, visible FPA CM	Mid-long IR, visible FPA CM
Electronic Attack (Passive Horizontal/Top Attack Detection)	Horizontal ATGM	Top attack smart munition	Low-observable horizontal and top attack munitions

Table IV–22. Technical Objectives for Electronic Warfare/Directed Energy Weapons (continued)

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
RF-Directed Energy Weapons	High power interference modulation source concept Multibeam klystron RF–DEW modulator	Silicon carbide hardening devices High average power traveling wave tubes (TWTs) Advanced RF–DEW pulsers	Techniques for hardening against upset High power wideband amplifiers Advanced conventional source systems Alternate source weapon systems
Lasers	Mid IR laser source <50 lb Package DAPKL	Mid IR laser with 10X power Compact 10X power solid-state laser	Lightweight all-band mid IR diode lasers Compact 100X power solid-state laser

Table IV–23. Electronic Warfare/Directed Energy Weapons Linkages to Future Operational Capabilities

Technology Subarea	Integrated and Branch/Functional Unique Future Operational Capabilities
Electronic Attack (Signal Processing)	TR 97–019 Command and Control Warfare
Electronic Support (Receivers)	TR 97–02 Situational Awareness TR 97–029 Sustainment TR 97–044 Survivability—Personnel
Electronic Attack (Antennas)	TR 97–019 Command and Control Warfare
Electronic Attack (Radar Jamming Techniques and Modulators)	TR 97–019 Command and Control Warfare TR 97–043 Survivability—Materiel
Electronic Attack (Fuze/Smart Munition Jamming)	TR 97–019 Command and Control Warfare TR 97–043 Survivability—Materiel
Electronic Attack (Fiber Optic Cable for IRCM/Laser Warning)	TR 97–019 Command and Control Warfare TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–043 Survivability—Materiel
Electronic Attack (IR Missile Jamming)	TR 97–019 Command and Control Warfare TR 97–043 Survivability—Materiel
Electronic Attack (Passive Horizontal/Top Attack Detection)	TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–043 Survivability—Materiel
RF Directed Energy Weapons	TR 97–005 Airspace Management TR 97–007 Battlefield Information Passage TR 97–010 Tactical Communications TR 97–043 Survivability—Materiel
Lasers	TR 97–035 Power Source and Accessories TR 97–036 Nonprimary Power Sources Combat Vehicles/Support Systems TR 97–043 Survivability—Materiel

L. CIVIL ENGINEERING AND ENVIRONMENTAL QUALITY

1. Scope

Technology efforts in this area solve critical environmental and civil engineering problems related to training, mobilizing, deploying, and employing a force at any location at any time. These efforts will provide the Army with enhanced capabilities for executing mobility, countermobility, survivability, and general engineering missions. They also provide the lowest possible environmentally sustainable, life-cycle cost, military-unique infrastructure required to project and sustain U.S. forces worldwide from CONUS or forward-presence bases.

Environmental Quality subareas include cleanup of contaminated sites, compliance with all environmental laws, pollution prevention to minimize Army's generation of wastes, and conservation of our natural and cultural resources. Civil Engineering subareas include conventional facilities, airfields and pavements, survivability and protective structures, and sustainment engineering. There is a tri-service joint engineers management panel to oversee, direct, and coordinate this program. The joint engineers panel consist of the flag officer engineer material developer for each service and is currently chaired by the Air Force under a 2-year rotation assignment. Technology subpanels in each major program area ensure coordination and nonduplication of research efforts.

2. Rationale

National and international laws and treaties demand the mitigation of environmental impacts resulting from normal operations and maintenance of Army training readiness and industrial activities. Base realignment and closure actions place an added urgency on bringing our sites into compliance while placing more activity on remaining installations, thereby creating greater demands on facilities and compliance requirements. Reduced budgets and increased regulatory requirements dictate the need for new or improved technologies to reduce the costs of contaminant cleanup, treatment, and disposal; reduce the generation of hazardous materials and pollutants; enhance compliance; and maintain natural and cultural resources in a realistic state to support training and operations. Payoff for investments in environmental quality technology is realized by reducing the cost of doing business while maintaining our mission readiness.

Civil engineering R&D provides the Army technologies to project and sustain U.S. Forces from CONUS and outside the continental United States (OCONUS) in the defense of this nation. The payoff in this area is threefold:

- Operation and maintenance (O&M) cost reductions free up dollars for mission critical activities.
- Infrastructure improvements of power projection platforms increase military readiness.
- Enhanced quality of life improves Army capability through increases in retention rates for soldiers.

Unique Army civil engineering needs arise from the characteristics of the weapons and transportation systems. The requirement to counter the effects of advanced conventional weapons and saboteur threats is not found in the private sector and, accordingly, there is no robust civilian R&D effort. The need to rapidly establish, maintain, and upgrade or retrofit facilities and transportation infrastructure within a theater of operation is unique; the private sector has no like requirement and no significant R&D investment. Our aging CONUS infrastructure (the average age of Army facilities is 35 years) requires modernization on a scale not seen elsewhere.

3. Technology Subareas

a. Civil Engineering

Goals and Timeframes

The primary thrusts in the conventional facilities area are to develop technologies to revitalize and operate DoD's aging infrastructure, to ensure effective strategic power projection platforms, and to maximize productivity of resources in acquisition, revitalization, operations, and maintenance and repair (M&R) management. The Army's $162 billion physical plant requires $5.9 billion annually to operate, maintain, and repair its aging facilities. The annual energy bill alone topped $1.5 billion, while the backlog of maintenance and repair (BMAR) of facilities is $2.2 billion. The goal is to achieve a 20 percent reduction in facilities acquisition and M&R costs from 1990 levels and a 30 percent reduction from 1985 levels in energy consumption by FY05. Technologies developed are dual use and critical to DoD cost reduction goals. Delivery of mission-enhancing, energy-efficient, and environmentally sustainable facilities with scarce resources is a major challenge. Every dollar saved from infrastructure improvements can be a dollar earned for mission-critical activities.

In the subareas of airfields and pavements, the goal is to reduce costs by 20 percent ($72 million per year) and extend the life (5 to 10 years) of the Army's military-unique roads, airfields, ports, and railroads by the year 2000. Potential payoff and transition opportunities include providing the U.S. military with a reliable launching platform to project mobile forces to support worldwide contingency conflicts. The Army's pavement research leads the nation. Civilian airports, 26 states, and many municipalities use the Army's airfield and pavement procedures.

For survivability and protective structures (S&PS), the goal is to provide reliable and affordable structural hardening and CCD that will increase survivability of facilities, equipment, and personnel against a broad spectrum of increasingly lethal modern weapon threats, ranging from terrorist attack through regional conflicts and up to limited nuclear warfare. Lightweight, highly ductile, and high-strength materials with enhanced energy absorption will reduce hardening costs. Retrofit of existing facilities will enhance survivability of large-length-to-diameter-ratio penetrators and blast and thermal weapons.

The sustainment engineering subarea is structured to provide the civil engineering technologies required by the Army for successful execution of strategic, operational, and tactical force projection, employment, and sustainment. Engineer troops will be able to support a deployed force in an austere theater with faster, lighter, less voluminous, and less manpower-intensive ways of executing mobility, countermobility, and general engineering missions. Transitions include technical and field manuals, guide specifications, and the Army's facility component systems.

Major Technical Challenges

Challenges for the conventional facilities subareas include technologies for affordable automated condition assessment, integrated installation management tools, innovative revitalization technologies, and technologies to determine applicability and DoD-wide prioritization of energy conservation opportunities to reduce O&M costs. Technology challenges for the S&PS subarea include innovative uses of lightweight, high strength, high ductility materials in protective construction and retrofit of existing structures to increase hardness at low cost and improve numerical models for accurate vulnerability assessments. Challenges for sustainment engineering include methods to improve construction speed and reduce logistic requirements, methods to acquire and interpret data for infrastructure assessment, and methods to predict real-time sea-state forecasts and logistics over-the-shore throughput assessments.

Army research is currently working to overcome technological barriers in civil engineering by developing:

- Collaborative automated environment to optimize conventional facility life-cycle costs by concurrent considerations of design, construction, operation, and maintenance.
- Breakwaters that can be rapidly installed to attenuate adverse sea-states for logistics over-the-shore operations.
- Material, admixtures, dynamic 3D models, and viscoelastic material responses for airfields and pavements.
- Criteria and materials for constructible survivability measures and simplified survivability (facilities, equipment, and troops) assessment capabilities for battlefield commanders.

b. Environmental Quality

Goals and Timeframes

The primary thrusts of site cleanup R&D are to reduce cost and expedite cleanup programs while ensuring protection of human health and the environment. R&D is conducted in characterization/monitoring, remediation technologies, and fate and effects of environmental contaminants in all climates. Cleanup R&D will produce innovative and cost-effective site identification, assessment, characterization, advanced cleanup methods, and monitoring technologies. By 2001, advanced sensors and sampling devices will expand the capabilities and precision of these systems. Subsurface conditions will then be better understood, thus increasing the efficiency of composting, unexploded ordnance (UXO) detection, in-situ biological treatment, passive subsurface water treatment, and improved chemical immobilization concepts and methods. Techniques will be developed to more accurately and rapidly determine the fate, transport, and effects of key DoD contaminants in soil and groundwater in all climatic conditions.

Compliance R&D will provide numerous technologies for advanced "end-of-the-pipe" control and treatment of hazardous, toxic, gaseous, liquid, and solid wastes when pollution prevention is not possible. Army systems, operations, and processes will be developed to meet existing and anticipated air, water, land, and noise regulations. R&D is focused on (1) characterization of pollutant and waste behavior, (2) media-specific control and treatment technologies, and (3) monitoring and assessment tools. Pollution prevention R&D will provide the Army with alternative materials, innovative manufacturing processes, and enhancements to daily activities to enable the Army to operate current and future production plants as well as to use its weapons systems. Overall efforts are focused on minimizing compliance requirements through new systems and processes that prevent or minimize pollution, with attendant reduction in production and product treatment costs.

Conservation R&D will provide sustainable support for realistic training and testing operation through improved understanding of natural and military operations processes affecting biological, earth, and cultural resources. R&D is focused on developing cost-effective technologies to mitigate military impacts, rehabilitate damaged resources, comply with environmental regulations, and support sustainable ecosystem management. The goal by the year 2001 is to develop an integrated modeling framework linking land capacity, land rehabilitation, and species/ecosystems impact models.

Major Technical Challenges

Challenges include:

- Site heterogeneity (soil, water, and climate).
- Complex mixtures of military-unique chemical compounds encountered at cleanup sites.
- Inherent complexity of physical, chemical, and biological phenomena.
- Density and opaqueness of earth media.
- Differences in acceptable risk.
- Need to understand and develop technologies that address the diversity and complexity of waste streams, composition of

wastes, the energetic instability of waste streams, and the destruction or conversion of wastes and contaminants without the production of unwanted or hazardous by-products.

- The need to adapt military ranges to changes in mission, equipment, and training, and the need to understand and manage complex ecosystems and their responses to stress.

Army research is currently working to overcome technological barriers in environmental quality by developing technologies and applications such as:

- Supercritical water oxidation, advanced oxidation processes, catalytic decomposition, biodegradation and "cometabolic" processes, sorption, separation, and conversion to reduce costs and increase efficacy of treatment and disposition.
- Replacement materials for existing solvents, soluble chromium, strong acids, bases, and oxidizers used in production and maintenance activities.
- Integrated sensors, sampling, modeling, and management technologies to maintain DoD activities while conserving natural and cultural resources that are protected by a variety of statutory requirements.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for civil engineering and environmental quality is shown in Table IV–24.

5. Linkages to Future Operational Capabilities

The influence of this technology area on TRADOC FOCs is summarized in Table IV–25.

Table IV–24. Technical Objectives for Civil Engineering and Environmental Quality

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Civil Engineering (Conventional Facilities)	Addition of new building types into current version of modular design system (MDS) to dramatically reduce delivery time of Army facilities Basic framework for an integrated installation management system to reduce costs of O&M for Army installations	Reduce facilities acquisition, M&R costs by 15% of 1990 Reduce energy consumption by 20% of 1985 Integrated maintenance management prioritization analysis and coordination tool (IMPACT)	Reduce facilities acquisition, M&R costs by 20% of 1990 Reduce energy consumption by 30% of 1985 (Executive Order 12902)
Civil Engineering (Airfields and Pavements)	New materials and design system to increase pavement life at reduced costs Database development and interactive design systems for pavement prediction Fracture and durability model field validation Develop improved mixture design for quality control and quality assurance	Fundamental understanding and analytical capability to address all aspects of pavement response and behavior Methods and materials for rapid construction of operating surfaces Reduced life-cycle costs and increased durability of DoD's pavement by 10% of FY93 cost	Criteria for aerial port of embarkation (APOE) power projection platforms Criteria for airfield design and construction to support contingency operation worldwide DoD transportation systems designed with confidence levels of service ability and performance 25% life-cycle cost reduction of FY93 cost

Table IV–24. Technical Objectives for Civil Engineering and Environmental Quality (continued)

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Civil Engineering (Survivability and Protective Structures)	Criteria for antipenetration systems to defeat heavy penetrators Procedures for retrofitting roofs and walls of existing facilities to provide protection from vehicle bombs Develop a family of protective systems using advanced materials and design procedures that will increase the survivability of troops (in fighting positions), weapon systems, materials, and equipment Quantity CCD signature-reduction techniques for materials used in fixed and relocatable assets	PC-based design manual for hardened structures Develop 5X to 6X conventional concrete strength at reduced cost for hardened facilities Antipenetration systems to defeat very heavy robust penetrators Lightweight, high-strength composite framing elements for hardening structures Deployable protective packages for light forces Automated CCD design/analysis capability	Vulnerability assessment model for retrofitting critical facilities to enhance survivability against advanced weapons Develop criteria for survivability of conventional facilities against entire spectrum of terrorist weapons Increase force survivability with 40% reduction in logistics burden Decrease probability of detection by 50% through advanced multispectral signature management techniques
Civil Engineering (Sustainment Engineering)	Field demonstration of advanced materials for construction of operating surfaces Determine mechanical properties of snow and ice as construction materials Validate and document mobility data inference routines for all of the world's major climatic zones Demonstrate obstacle planning software	Reduce construction time in soft soil by 35% First-generation theoretical mobility model Design for rapidly installed breakwater First logistics over-the-shore operational simulator (LOTSOS) Automated bridge classification system	Reduce horizontal construction time by 20% Reduce logistic requirements for engineer construction materials by 20% High-resolution mobility model for advanced vehicle platforms Gap/river crossing site selection procedures based on trafficability and crossability
Environmental Quality (Conservation)	Plant succession model for impact prediction and recovery potential Complete guidelines for 30% reduction in streambank erosion	Provide knowledge, approach, and tools to match land use and land capacity in selected ecoregions Models to simulate mission impacts on key protected species	75% reduction in soil erosion on bases Risk-based ecosystem use models
Environmental Quality (Cleanup)	Advanced oxidation treatment for explosives in groundwater In-situ treatment of heavy metals Groundwater modeling system	Biotreatment of explosives in soils Fate and transport risk assessment model On-site assessment visualization	Remote multisensor UXO detection In-situ biotreatment of explosives in soil Supercritical water oxidation for destruction of waste
Environmental Quality (Compliance)	Guidance for intelligent application for advanced oxidation (ADVOX) processes for munitions production waste 25% reduction of volatile organic compounds (VOCs) in manufacturing energetics Nitrocellulose fine treatment	Treatment of advanced energetic materials used for propellants Advanced maintenance technology to reduce the cost of operating energetic manufacturing facility pollution control equipment	90% reduction in VOC emissions from production facilities

Table IV–24. Technical Objectives for Civil Engineering and Environmental Quality (continued)

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Environmental Quality (Pollution Prevention)	Ozone depleting substance (ODSs) elimination for refrigerants, sealants, and degreasing cleaners Laser ignition to replace chemical ordnance to medium and large caliber ammunition (avoid toxins during manufacture and demilitarization) Improved tools/models for life-cycle environmental analysis to assist weapon designers and program managers	Low VOC reformulated chemical agent resistant coating (CARC) paints Thermoplastic elastomer propellants elimination in the manufacturing process Green bullets (elimination of lead in primers and bullet cores) Alternative technologies to avoid open burn/open detonation of energetics (scrap/demilitarization)	Green missile (lead elimination and no hydrocyanic acid (HCI) emission) Green barrel (elimination of hexavalent chromium in waste water) Halon 1301 replacement for ground tactical vehicles and aircraft engine protection (ODS problem solved) Cleaner processes and products for energetics Aqueous processes for ceramics and composites

Table IV–25. Civil Engineering and Environmental Quality Linkages to Future Operational Capabilities

Technology Subarea	Integrated and Branch/Functional Unique Future Operational Capabilities
Civil Engineering (Conventional Facilities)	TR 97–007 Battlefield Information Passage TR 97–019 Command Control Warfare EN 97–014 Provide, Repair, and Maintain Logistics Facilities EN 97–015 Procurement and Production of Construction Materials
Civil Engineering (Airfields and Pavements)	TR 97–007 Battlefield Information Passage EN 97–015 Procurement and Production of Construction Materials EN 97–028 Engineering Support to Nonmilitary Operation
Civil Engineering (Survivability and Protective Structures)	TR 97–007 Battlefield Information Passage TR 97–019 Command Control Warfare TR 97–043 Survivability—Materiel EN 97–014 Provide, Repair, and Maintain Logistics Facilities EN 97–015 Procurement and Production of Construction Materials
Civil Engineering (Sustainment Engineering)	TR 97–007 Battlefield Information Passage TR 97–019 Command Control Warfare EN 97–014 Provide, Repair, and Maintain Logistics Facilities EN 97–015 Procurement and Production of Construction Materials EN 97–028 Engineering Support to Nonmilitary Operation
Environmental Quality (Conservation)	TR 97–012 Information Systems EN 97–001 Develop Digital Terrain Data EN 97–002 Common Terrain Database Management EN 97–028 Engineering Support to Nonmilitary Operation
Environmental Quality (Cleanup)	EN 97–028 Engineering Support to Nonmilitary Operation
Environmental Quality (Compliance)	TR 97–019 Command Control Warfare EN 97–014 Provide, Repair, and Maintain Logistics Facilities EN 97–028 Engineering Support to Nonmilitary Operation
Environmental Quality (Pollution Prevention)	TR 97–007 Battlefield Information Passage TR 97–019 Command Control Warfare EN 97–014 Provide, Repair, and Maintain Logistics Facilities EN 97–015 Procurement and Production of Construction Materials EN 97–028 Engineering Support to Nonmilitary Operation

M. BATTLESPACE ENVIRONMENTS

1. Scope

The battlespace environments technology area encompasses the study, characterization, prediction, modeling, and simulation of the terrestrial, ocean, lower atmosphere, and space/upper atmosphere environments. The goals are to understand their impact on personnel, platforms, sensors, and systems; to enable the development of tactics and doctrine to exploit that understanding; and to optimize the design of new systems.

Technology subareas for battlespace environments in the *Army Science and Technology Master Plan* (ASTMP) are organized around a particular taxonomy that is specified in the sensors, electronics, and battlespace environment chapter of the DTAP prepared for OSD DDR&E. The two technology subareas that apply to the ASTMP are terrestrial environments and lower atmosphere environment.

2. Rationale

Commanders at all levels must know how the environment will impact their operations as well as the operations of their adversary and use this knowledge for military advantage. Sensor and weapon system developers must also understand the environment's effects on system performance to optimize design effectiveness. This investment will provide the following improvements to future warfighting capabilities:

- An order of magnitude improvement in providing digital topographic data needed by the commander for optimized deployment, mobility, planning, and logistics support.
- High resolution weather forecasts for incisive decision making and enhanced operational capability in adverse weather; reduced weather-related damage, and fuel costs.
- Realistic representation of dynamic environment and terrain in simulations to permit more effective mission planning, rehearsal, and training.
- Realistic portrayal of the effects of the Battlespace Environments to reduce operational costs and reduce casualties.

3. Technology Subareas

a. Terrestrial Environments

The terrestrial environments subarea consists of technology developments in the areas of cold regions engineering research and topography. Emphasis in the terrestrial environments subarea is on the study, characterization, and modeling of the physical phenomena, processes, interactions, and effects associated with terrain, its surface features, and the overlying atmosphere at scales of interest to ground combat forces (see Figure IV–10).

Cold regions engineering research focuses on mitigating the adverse effects of snow, ice and frozen ground on both materiel and winter operations. Topographic research is focused on better knowledge of the terrain through improved geospatial data generation, data management, analysis, and modeling through the exploitation of multisensor data. Objectives in terrestrial environments technology development include:

- Demonstrate an integrated dynamic IR/MMW terrestrial background scene generation capability for synthetic environments (FY98).
- Develop image perspective transformation technology for use with imagery to rapidly evaluate sub-10-meter resolution terrain data and position reality (FY98).
- Demonstrate VR-based battlefield environments that place the soldier in an environment with replicated terrain and climate, creating a highly detailed realistic setting for training and mission planning/rehearsal (FY98).

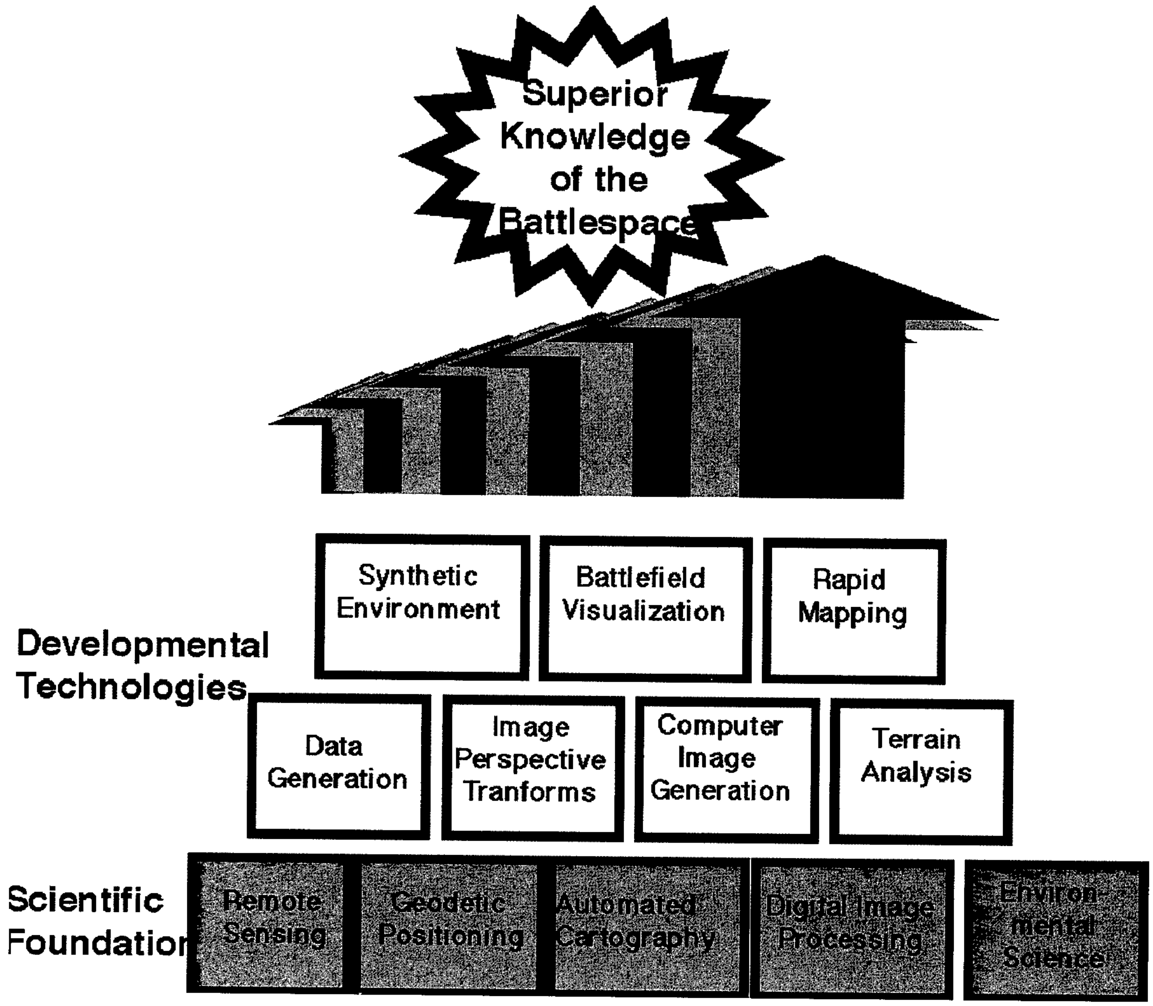


Figure IV–10. Topography Science and Technology

- Develop model-generated passive/active IR and background scenes of winter terrain for predicting sensor performance and design (FY02).
- Demonstrate spatially distributed, physics-based, 3D ground state and weather effects in future distributed interactive simulations (FY03).
- Develop multiscale/multiproduct geospatial data generation software capable of generating large integrated terrain databases at multiple levels of detail (FY03).
- Estimate knowledge-based performance for dual and multimode sensing systems operating in IR, MMW, and RF energy regimes over winter-impacted terrain (FY07).
- Develop battlespace fly/walkthrough and automated terrain analysis capability (FY07).
- Develop dynamic environment and terrain (DET) implementation for use with computer-generated forces (FY07).
- Demonstrate knowledge-based systems for predicting the performance of multimode sensing systems (IR and MMW) over winter-impacted terrain (FY08).
- Demonstrate automated feature extraction and attribution capability (FY08).

Cold Regions

Cold region engineering focuses on minimizing or eliminating the dramatic effects of winter weather on operations conducted by the Army. To do this, effective decision making tools such as models, simulation, and mission planning/rehearsal factors are required that accurately predict state of the ground, atmospheric conditions, and system performance in complex cold region environments. The winter environment presents a severe challenge to the performance and operability of weapon systems, target identification and acquisition sensors, equipment, and personnel. This challenge is not confined to the effects of temperature. It also includes the detrimental effects of snow, ice, and the state of the ground, whether frozen or thawing. Frozen and thawing soils greatly affect the projection and mobility of forces, mine clearing operations, and earth excavation required for force protection and construction. Snow, ice, and frozen ground dramatically alter the propagation of acoustic and seismic energy and IR with IR and MMW signatures. This greatly reduces the effectiveness of weapon systems and sensors. Icing conditions dramatically change fixed and rotary winged aircraft performance, impact safe operation of equipment on roads, airfields, and bases, and impact the ability to communicate. Technical challenges in this area relate to developing and validating models of these phenomena, and finding ways to enable operations to continue in spite of them. The cold region technology effort objectives are to:

- Develop first principle models to predict the multispectral signatures of winter terrain surfaces and features for imaging sensor systems. Models will be structured to provide simulation capabilities for evaluating environmental constraints early in the development cycle of sensor systems, and to provide realistic physics-based backgrounds for training simulations.
- Determine procedures and equipment criteria enabling combat engineering operations to function effectively in winter conditions. This includes use of snow and frozen ground for expedient fortifications, facilities, roadways, and excavations, and operation of engineering equipment under winter conditions.
- Develop models of equipment and unit performance in winter conditions in sufficient detail to enable realistic simulation of these effects in interactive synthetic environments.

Major Technical Challenges

- Acoustic energy propagation is distinctly different in winter than in summer. The technical challenge is understanding the coupling that occurs between the complex air, snow, frozen-ground, and unfrozen-soil interfaces.
- IR, MMW, and radar interactions with winter terrain surfaces (i.e., snow, ice, frozen soil) vary dramatically with changing meteorological conditions. The challenge is to model and predict the response.
- The impacts of low temperatures, snow, ice, frozen ground, and ice accumulation on the performance of materiel and equipment must be characterized to support design modifications, the formulation of alternative techniques or procedures, and the prediction of the extent and duration of the impacts.

Development Milestones

- Distribute background energy transfer model over a variety of complex terrain and meteorological conditions (FY98).
- Incorporate icing radiosonde data into models for predicting aircraft icing severity (FY98).
- Provide the Army Engineer Center and School with techniques, kits, and support systems to reduce low temperature degradation of engineer materiel performance (FY98).

- Provide critical data for integrated winter operation tactical decision aids (TDAs) (FY99).
- Integrate seismic-acoustic sensor performance in a synthetic environment to optimize sensor performance (FY00).
- Transition model of the spatial variability of atmospheric icing to support communications and aerial operations TDAs to the U.S. Army Aviation Center and School and the U.S. Army Intelligence Center and School (FY00).
- Integrate physics-based multiband dynamic environment models for prediction of sensor performance and optimizing sensor design (FY01).
- Demonstrate knowledge-based systems for predicting the performance of multimode sensing systems (IR and MMW) over winter-impacted terrain (FY03).

Topography

Knowledge of topography is essential to a common picture of the battlespace. Providing accurate and current information to the warfighter is the focus of topographic R&D. Efforts are needed to provide technology for rapid digital terrain feature and elevation data generation, data management, terrain visualization, terrain analysis, and realistic mission training and rehearsal. The warfighter needs improved capabilities in all these areas to gain information dominance, shape the battlespace, and conduct decisive operations.

Topographic science is the delineation and representation of positions and elevations of natural and manmade features. S&T efforts are concentrated in the areas of standards, generation, analysis, representation, and management/dissemination. Developments focus on exploitation of multisource/multiresolution sensors, validation of geospatial data and algorithms, dynamic physics-based visualization and modeling, surveying/positioning, and the design of a smart digital map for the soldier.

Objectives in topographic and geospatial information development include:

- Demonstration of advanced technologies in digital feature extraction and attribution, data management, positioning technologies beyond the GPS, and the implementation of dynamic terrain into mission planning, rehearsal, and training systems.
- Use of knowledge-based techniques to improve terrain data exploitation for detecting and identifying geospatial changes and to predict terrain and climate effects over time in support of battlefield decision making.
- Reduction of the time required to generate realistic environments in distributed modeling and simulation.

Major Technical Challenges

- Identifying terrain features/targets automatically to respond within the enemy's decision cycle.
- Developing a total force positioning and navigational capability for the Army. Accurate fire and the ability to locate and navigate will be key to success on the obscured future battlefield.
- Promulgating standard verified and validated software to achieve joint interoperability goals.
- Generating terrain and weather environments in near-real time for tactical operations and distributed modeling and simulation.
- Developing a methodology to determine the effects of geospatial data and terrain based models on battlefield decision aids and to display the results to a commander in order to minimize risk.

Development Milestones

- Integrate multispectral imagery/hyperspectral imagery with digital terrain elevations for terrain feature extraction (FY98).

- Devise neural network image data classification system (FY98).
- Develop new methods for portraying terrain analysis product reliability (FY98).
- Incorporate techniques for processing synthetic aperture radar (SAR) and interferometric synthetic aperture radar (ISAR) feature data in existing software (FY98).
- Improve visualization capabilities with the addition of dual-band IR and image intensifier capability (FY98).
- Test link capability for point and line/vector geospatial data management (FY99).
- Develop standards for the representation and content of a link structure for geospatial data (FY99).
- Develop advanced tactical navigator (ATN) for combat support (CS)/CCS vehicle usage (FY99).
- Link 3D model and texture library to database generation capability (FY99).
- Incorporate automated feature extraction techniques from spectral, SAR, and EO sources into existing digital stereo photogrammetric software (FY00).
- Extend physics based models and visualization capability to incorporate passive and active MMW (FY00).
- Develop off vehicle ATN (FY01).
- Test the link capability for complex geospatial areal data management (FY01).
- Deliver algorithms for management, dissemination, and integration of geospatial information to industry through the Open Geographic Information System (OpenGIS) consortium (FY01).
- Test initial automated feature attribution capability based on terrain reasoning software (FY01).
- Integrate mode derived IR and MMW sensor performance overlays into 3D visualization (FY01).
- Investigate capability for automated feature attribution based on terrain reasoning (FY01).
- Demonstrate visualization and command planning tools for urban data sets (FY01).
- Improve terrain data inferencing methodologies (FY02).
- Develop a spectrally enhanced multisensor exploitation capability (FY02).

b. Lower Atmosphere Environment

The lower atmosphere environment encompasses the global surroundings where Army personnel and systems function, at times and spaces for which commercial weather data and products are unavailable or insufficient. This subarea focuses on joint service weather requirements and capabilities. One particular service will assume the lead in specific research and development areas, and that work will be adapted by other services. The Army's efforts in these areas are in accordance with objectives laid out in the DTAP, and involve atmospheric measurements, data ingest and distribution, prediction, simulation, and development of system-specific, and tailored weather decision aids. The following discussion breaks the Army contributions into three technology thrusts: current battlespace weather, predicted battlespace weather, and decision aids.

The goal of the *current battlespace weather* thrust is to provide the ability to determine weather information for a battle-size area anywhere in the world. This is accomplished through direct or remote sensing of atmospheric parameters. The *predicted battlespace weather* thrust concentrates on methods to predict atmospheric conditions over a battle-size area for any time from the present up to 2 weeks in the future. These predictions use analysis of any available data, as well as meteorological modeling. The goal of the *decision aid* thrust is to provide information to warfighters on the effects of the current and predicted atmospheric conditions on friendly and threat

warfighting capabilities. This involves assimilating and disseminating weather information and threshold values for all weather sensitive systems in order to produce tailored decision aids.

These thrusts, as detailed below, all contribute to providing knowledge of the lower atmosphere environment and its effects to gain an advantage on the battlefield.

Current Battlespace Weather

Accurate and timely weather and atmospheric information over critical parts of the battlespace will provide future higher resolution forecast models with the initialization data to increase their accuracy. Combining the new capabilities of remote sensing systems operating from ground, air, and space platforms with covert, small signature, in situ sensor platforms will result in new real-time data concerning the battlespace and target area meteorology environment. The changing role of U.S. forces into a reactive force deployed to global small-scale conflicts requires that this information be available on extremely short notice throughout the world. With the evolving capability of high resolution battlespace forecast models, as discussed below, these data will provide the critical initialization information and confirm the model predictions for commander confidence in planning decisions. Basic research focuses on the measurement of small-scale phenomena in the planetary boundary layer, including aerosols, along with weather parameters (see Figure IV–11). Specific objectives include:

- Extract battlespace weather and atmospheric information from satellite active remote sensors. Provide data from ground to space with four times the accuracy of current passive sensors, covering 40 percent of the global surface in under 4 hours.
- Automate data retrieval from tactical weapon platforms. Increase battlespace data collections by a factor of five over current sensors.
- Provide seamless data distribution between services and tactical areas. Enable common, joint data collection and communication to allow all services to share data in real time for a consistent, accurate "nowcast" common picture of the battlespace.
- Develop ground-based remote sensors that operate "on the run" to support future force mobility. Provide data at much higher rates than today's technology.
- Develop a prototype mobile atmospheric profiler system, which, when coupled with meteorological (met) satellites and other battlefield met data sources, eliminates the requirement for logistically burdensome artillery balloon borne sensors and hydrogen generators.
- Provide quantitative assessments of the propagation characteristics and radiative transfer effects of natural clouds and man-made battlefield aerosols that affect illumination, boundary layer energy balance, surface state, and visibility, through studies of MMW propagation and aerosol detection.
- Develop advanced laboratory measurement techniques and instrumentation as tools for aerosol microphysics diagnostics and for the detection and identification of CBW agents.
- Develop aerosol and gaseous information sufficient to quantitatively model atmospheric limitations on military systems that rely on radiation (UV, visible, IR, and MMW) for detection, imaging, and identification.
- Develop and test ground-based remote sensors for battlefield atmospheric characterization of the dynamic and thermodynamic properties of aerosol and gases, such as temperature, density, wind fields, water vapor, and CBW agents. Evaluate the ability of satellite remote sensors to support this same purpose.

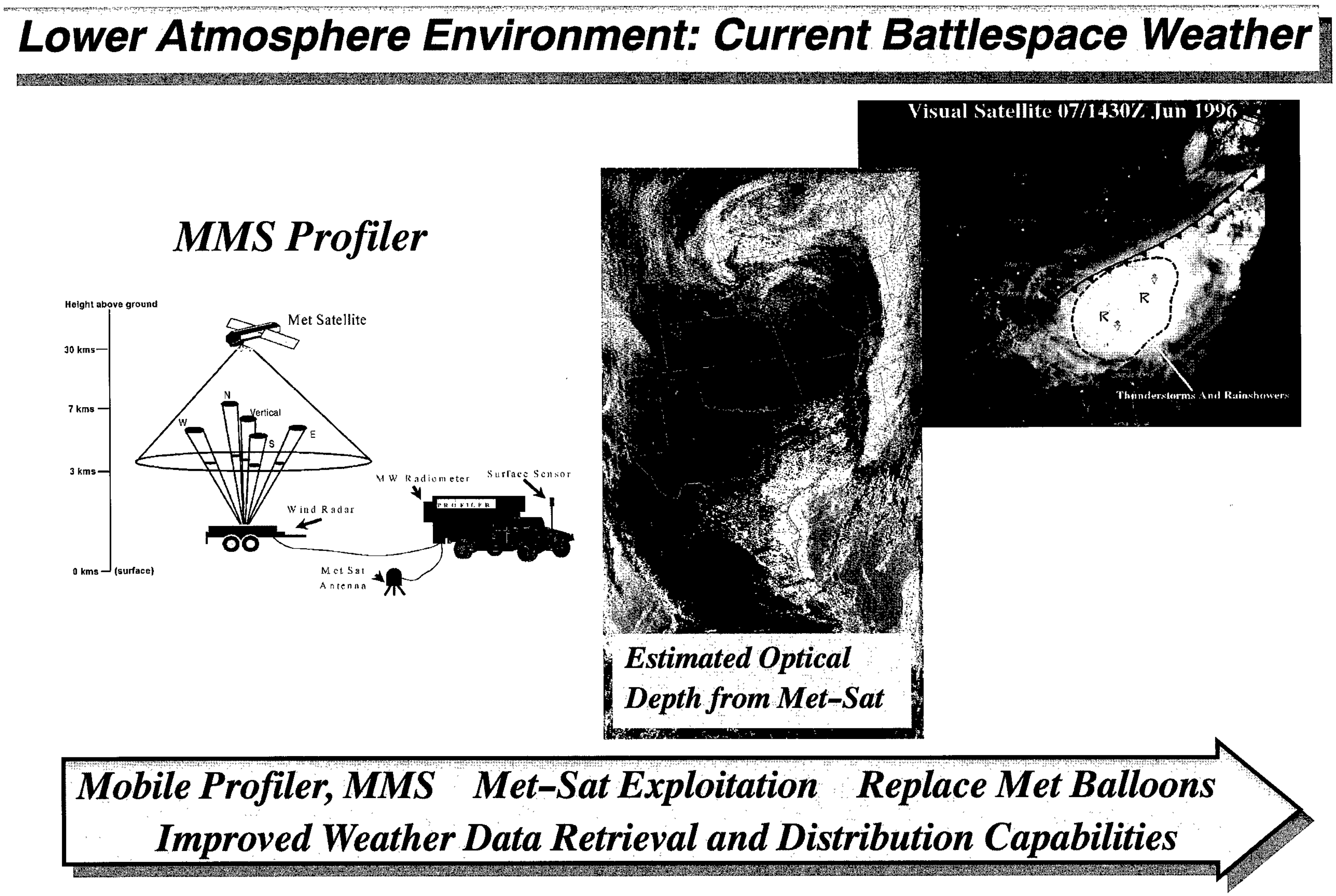


Figure IV–11. Measurements in the Planetary Boundary Layer, Along With Weather Parameters

Major Technical Challenges

- Develop remote sensor concepts and algorithms to provide tactical data for initializing battlefield meteorological models, assessing performance of precision strike weapons, and general real-time situational awareness on the battlefield.
- Develop measurement systems that resolve the microscale dynamic structures for the verification of atmospheric models operating at these scales. Technical barriers for basic research involve the investigation and explanation of previously unobservable atmospheric phenomena occurring at these scales, such as the convective boundary layer, gravity waves, and shear instabilities.
- Determine the characteristics of aerosols, their dynamic properties in the atmospheric medium, and their optical properties over all spectral bands of military interest, and develop the instrumentation that permits the detection and analysis of aerosols.

Development Milestones

- Complete development of a prototype atmospheric profiler as an upgrade to the Army's meteorological measuring set (MMS) (AN/TMQ–41) and demonstrate during 4th Infantry Division (4ID) digitized rotation at the National Training Center (NTC) (FY98).
- Automate data retrieval from MMS to the integrated meteorological system (IMETS) using variable message format (VMF) bit-oriented message (BOM) protocol (FY98).
- Automate data retrieval from Improved Remotely Monitored Battlefield Sensor System (IREMBASS) met sensor (FY99).
- Complete development of neural net software for direct retrieval of wind speed and direction from met satellite radiance data. Improve the accuracy of met satellite measured winds by 50 percent (FY99).
- Develop remote sensing analysis algorithms to provide improved initialization data for battlescale forecast models including surface energy balance interactions, boundary layer temperatures and winds, water vapor, and cloud liquid water data (FY00).
- Develop remote sensing analysis methods to estimate surface layer visibilities, and identify low stratus and fog regions and their effects on local illumination and contrast (FY02).

Predicted Battlespace Weather

Relying on the Navy and Air Force large-scale, long-term prediction models allows the Army to concentrate on resolving the smallest battlespace scales, below 1 km in space and 1 hour in time. As advances in the regional and theater scale models allow reliable forecasts beyond 10 days, the Army will reduce the space and time scales to 100 meters/1 minute and below to resolve the boundary layer processes that influence the propagation of acoustic and EO energy, and the motion and dilution of CB agents on the battlefield. Running as nested applications below the large-scale models, the battlespace model will provide the spatial and temporal data filling in the features missed by the larger models but that are of prime importance to the Army. Basic research focuses on transport and diffusion modeling and optical effects of the atmosphere on propagation through turbulence (see Figure IV–12). Specific objectives include:

- Optimize environmental prediction models to allow operation on virtually all tactical weapon systems, from the future soldier to artillery and missile systems. Provide more accurate and timely data for platform-specific decision aids.
- Develop a standalone analysis system that will emphasize key weather elements and weather phenomena for important decision making factors, which

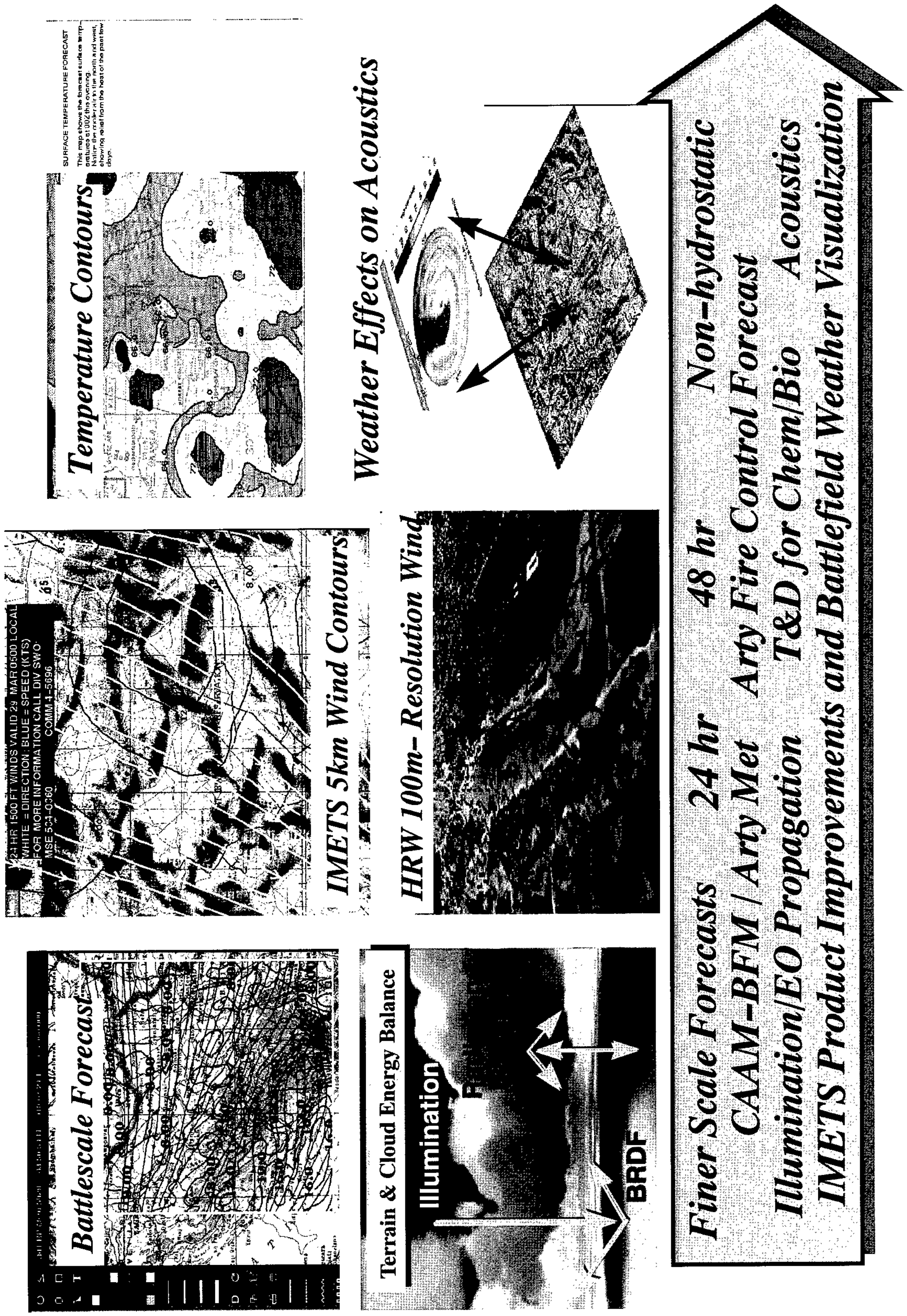


Figure IV–12. Lower Atmosphere Environment: Predicted Battlespace Weather

can serve all services for the purpose of improving nowcasting, forecast guidance products, and, potentially, the analysis in the mesoscale numerical weather prediction system.

- Increase firing accuracy of indirect fire cannon and missile systems by integrating the battlescale forecast model (BFM) directly into the ballistic kernel operating on fire direction center and gun platform fire control computers and use the BFM to calculate in near-real time the meteorological effects over the entire trajectory path of a projectile, rather than just at apogee.
- Build a mesoscale numerical weather prediction system appropriate for battlescale applications, including the boundary layer. The system should be capable of assimilating a wide range of data over complex inland and coastal terrain and accounting for improved cloud and aerosol treatment in the model physics, improved surface energy balance and evapotranspiration processes, and physical process oriented forecast models.
- Develop descriptions of the dynamic flow interactions with highly complex terrain, vegetation, and structures that can run on a variety of computer systems, from battlefield workstations to supercomputers.
- Improve modeling of transport and diffusion (T&D) of gases, particulates, and pollutant plumes essential to the DoD's CBW R&D programs. Couple T&D models to mesoscale numerical weather models to forecast aerosol dispersion and concentration.
- Link battlescale forecast models with gas/aerosol transport and diffusion models to provide four-dimensional (4D) predictions of CB agent threats on the future battlefield. Increase accuracy of spatial forecast by 50 percent and concentration forecasts by 60 percent.
- Understand and model the propagation of acoustic and short wavelength electromagnetic radiation in the atmosphere under natural and battle induced conditions.
- Develop high spatial and time resolved effects of weather and illumination variations on EO propagation and target background signature models.

Major Technical Challenges

- The computational speed and memory/storage required to resolve the mesoscale phenomena and to represent and predict mesoscale physical processes is extraordinary. The T&D of gases and particulates require treatments more sophisticated than traditional Gaussian plume models to represent the turbulent, chaotic nature of atmospheric motions. Technical barriers for basic research involve the development of probability density function (PDF) solutions in order to predict the concentration fluctuations, a critical issue for soldier system exposure, and the development of improved nonlinear solutions for the Navier–Stokes equations that describe the physical process of T&D.
- The flow of the atmosphere around and through vegetative canopies and through urban "canopies" plays a critical role in the use of countermeasure aerosols and for chemical and biological defense. Models of such flow must be available for operation on tactical systems.

Development Milestones

- Quantify the accuracy achievable by moving the BFM from the AN/TMQ–41 MMS to indirect fire control computers and using the BFM to correct for met effects over the entire trajectory path of a projectile (FY98).
- Develop improved capabilities to visualize forecast meteorological data and derived weather parameters in 3D on the tactical IMETS (FY98).

- Develop interfaces to allow tactical battlescale forecast data and derived propagation and illumination parameters to be provided through the Master Environmental Library to support high level architecture (HLA) simulations (FY99).
- Incorporate remote sensing and analysis of surface energy balance and surface state data to improve initialization of the battlescale forecast model (FY00).
- Extend accurate high resolution weather forecast capability for the battlefield to 48 hours (FY03).
- Deliver a nonhydrostatic moisture microphysics BFM for clouds and precipitation forecasts to the IMETS. Improve adverse weather forecasts by 40 percent while running on Army tactical computers (FY05).

Decision Aids

Mission planning and weapon selection on a future highly mobile, extremely lethal battlefield will require the commander to have available the best possible information on the impact of the weather and atmosphere on the mission objective. Decision cycles will shorten, forces will be more dispersed and independent, and thus future decision aids must operate on the tactical platforms, using all the data the sensors and model provide and providing the output in the most effective assimilation format. Weather impact decision aids will allow the commander to employ the weather as a combat multiplier (Figure IV–13). Specific objectives include:

- Develop integrated weather/atmospheric data, broad spectrum propagation models and advanced visualization methods, to provide 3D visualized decision aids showing graphical depictions of atmospheric impacts on mission plans and weapon use for current and future battlefields.
- Automate mission planning tools based on detailed knowledge of environmental impacts, to optimize the commander's planning and decision making ability. Improve the required mission output, as defined by the commander, by 30 percent over current methods.
- Integrate atmospheric and background models with target prediction models to ensure that atmospheric effects are included in the assessment of weapon system performance, survivability, and vulnerability.
- Develop more quantitative methods to augment current rule-based, binary decisions based on weather-dependent critical values for subsystem, system, platform and military operations performance.
- Develop environmental decision aids for operational and tactical levels of war planning and training that give the effects and impacts of weather and battle-induced atmospheres on U.S., allied, and threat unit functions, systems, subsystems, sensors, and personnel.
- Develop real-time weather and environmental effects models (obscurants, illumination levels, EO, and acoustic propagation) to provide common, unified weather effects, features, and representations leading to improved battlescale forecasting for simulation, training, doctrine, and C^3 systems that are compatible for all services.

Major Technical Challenges

- Battlespace prediction models and parameterization methods for boundary layer physical processes will depend crucially on in-theater data assimilation methods that fully exploit all sources of weather observations from remote and in situ platforms. Development of robust and flexible procedures will be needed to adapt to the available data options in real time.
- As the observation data from various sensors and platforms increase and the

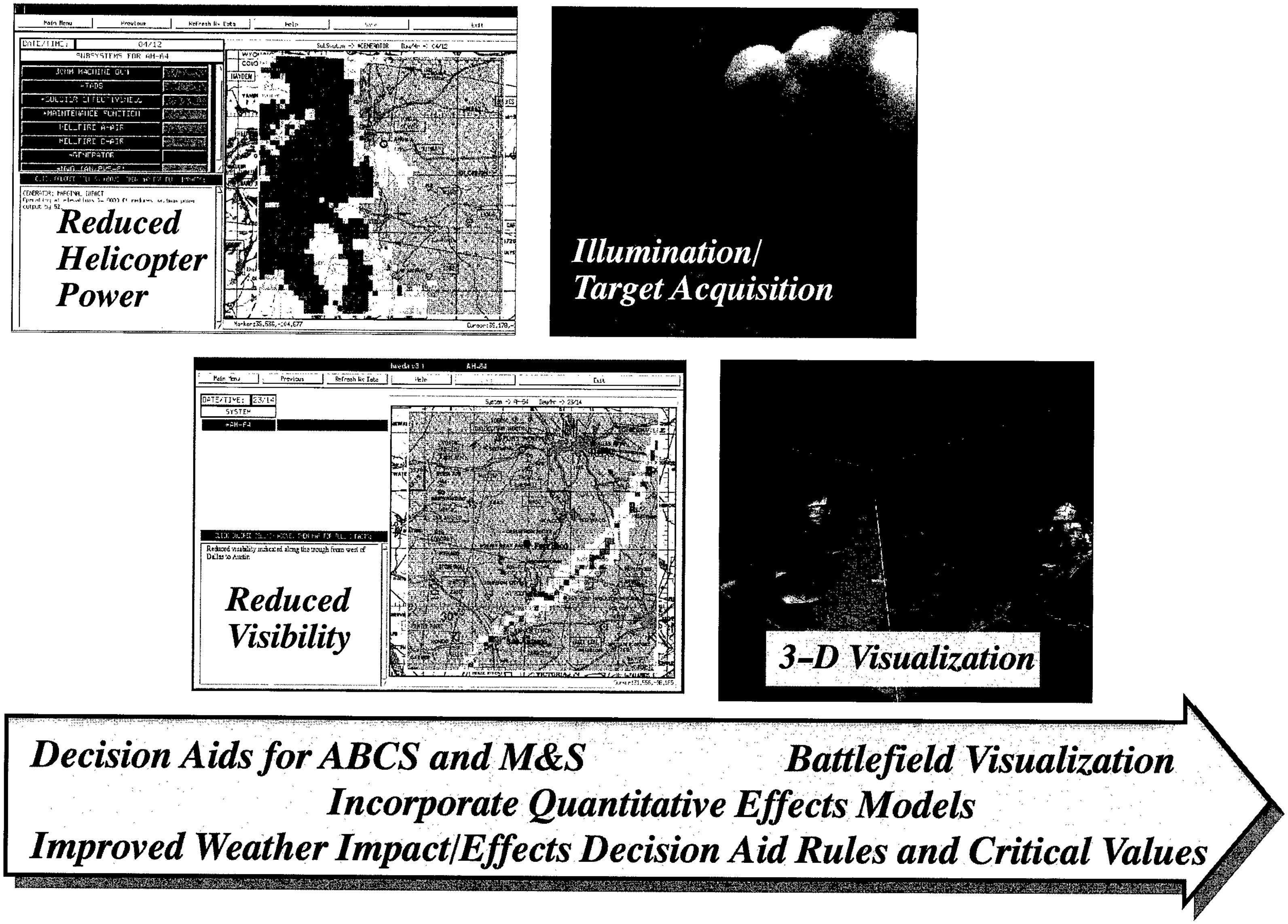


Figure IV–13. Lower Atmosphere Environment: Weather Decision Aids

fusion and prediction are highly synergized, quality control is essential to ensure an accurate description of the state of the atmosphere.

- The extension of weather impact decision aids from current rule-based, critical value threshold comparisons to more complex interactions between weather, terrain and performance characteristics will require greater use of AI, fuzzy logic, and expert system techniques that will increase computational loads.

Development Milestones

- Provide an integrated weather effects decision aid with a dynamic rule editor capability, allowing users from various functional areas to tailor weather impact threshold values to meet their particular mission requirements (FY98).
- Demonstrate integrated EO/acoustic/gas/biological agent propagation with tactical weather data and 3D visualization tools for mission planning at a division-level advanced warfighter experiment (AWE). Improve multicomponent mission planning by 40 percent over current binary decision aid technology, improve information assimilation by 60 percent over 2D map decision aid displays (FY98).
- Demonstrate decision aids that display 3D acoustic propagation over terrain (FY98).
- Demonstrate use of fuzzy logic and other AI methods to produce dynamic rules and weather-influenced system performance values to augment weather impact decision aids (FY99).
- Incorporate remotely sensed weather data and derived parameters to augment decision aid overlays (FY00).
- Demonstrate satellite remote sensing of battlespace environments and tactical use of such information in operational decision aids to the Communications–Electronics Command (CECOM) (FY01).

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Battlespace Environments is shown in Table IV–26.

5. Linkages to Future Operational Capabilities

The influence of this technology area on TRADOC FOCs is summarized in Table IV–27.

Table IV–26. Technical Objectives for Battlespace Environments

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Cold Regions	Provide physics-based dynamic winter effects on terrain models for inclusion into the synthetic battlefield Develop seismic-based target tracking and ranging capability for winter environments Develop remote icing accumulation detection method to support winter operations Develop low temperature/thermal cycling performance criteria for composite materials	Enhance physics-based 3D representation of complex terrain and weather conditions with modeling architectures that will allow practical application within DISNs Provide DET simulation for cold regions Develop methods to predict and alleviate the effects of ice accretion on military equipment to include aviation, communications, and sensors Validate low-temperature/thermal cycling performance criteria for new composite materials for Army applications	Enhance performance of smart and brilliant weapons and surveillance systems development to distinguish target signatures within complex winter backgrounds

Table IV–26. Technical Objectives for Battlespace Environments (continued)

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Topography	Incorporate techniques for processing SAR and ISAR feature data into existing software Incorporate/test initial spectral imagery automated feature extraction capability Improve visualization capabilities with the addition of dual-band IR and image intensifier capability Apply physics-based models to simulation applications Test link capability for point and line/vector geospatial data management Develop standards for the representation and content of a link structure for geospatial data Develop ATN for CS/CCS vehicle usage Complete small screen map display study	Incorporate automated feature extraction techniques from spectral, SAR, and EO sources into existing software Test initial automated feature attribution capability based on terrain reasoning software Extend physics based models and visualization capability to incorporate passive and active MMW Integrate mode derived IR and MMW sensor performance overlays into 3D visualization Test the link capability for complex areal data management Deliver algorithms for management, dissemination and integration of geospatial information to industry through the OpenGIS consortium Develop off vehicle ATN Provide multiscale/multiproduct terrain visualization software	Investigate emerging satellite data for enhanced terrain feature generation and direct 3D imaging Investigate real-time automated feature attribution using multi-source data Develop real time dynamic atmospheric modeling Investigate and develop capability for fully automated real-time terrain visualization
Current Battlespace Weather	Downsize prototype mobile Profiler for mounting on top of high mobility multipurpose wheeled vehicle (HMMWV) shelter Demonstrate client/server architecture during division AWE Provide automated data retrieval from the MMS to the IMETS Provide automated data retrieval from IREMBASS met sensor	Develop capability to determine wind speed and direction from satellite radiance data Provide seamless weather data distribution between services Develop capability to identify biowarfare agents with portable biodetector	Replace met balloons on battlefield with Profiler Automate data retrieval from tactical weapon platforms
Predicted Battlespace Weather	Transition 24-hr BFM as server for weather effects clients on Army Battle Command System Develop computer assisted artillery meteorology (CAAM) time space weighted model and BFM on MMS for increased artillery accuracy Demonstrate ability to determine wind flow over complex terrain and land use features such as vegetative canopies and built-up areas Incorporate illumination, target, and scene shadow effects into target acquisition model Demonstrate BFM and weather effects integrated into the common operating picture seamlessly overlayed on terrain battlefield visualization products	Extend BFM to 48 hours, with higher resolution and increased accuracy Incorporate BFM in indirect fire control computer to increase artillery accuracy Incorporate terrain and weather effects into operational CB hazards prediction model	Provide horizontal/seamless integration of automatic battlescale weather forecasting throughout Army Battle Command System Develop 3D acoustic propagation model for 20 km ranges

Table IV–26. Technical Objectives for Battlespace Environments (continued)

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Decision Aids	Integrate realistic weather from BFM and decision aids into environmental libraries for HLA simulations Integrate weather effects decision aids into Army Battle Command System	Provide Integrated Weather Effects Decision Aid as tri-service software toolkit Develop decision aids that display 3D sound propagation over complex terrain Develop battlefield acoustic/seismic detection weather effects simulation	Meet weather requirements of advanced battlefield visualization systems and HLA simulations

Table IV–27. Battlespace Environments Linkages to Future Operational Capabilities

Technology Subarea	Integrated and Branch/Functional Unique Future Operational Capabilities
Cold Regions	TR 97–002 Situational Awareness TR 97–003 Mission Planning and Rehearsal TR 97–005 Airspace Management TR 97–006 Combat Identification TR 97–015 Common Terrain Portrayal TR 97–019 Command and Control Warfare TR 97–020 Information Collection, Dissemination, and Analysis TR 97–043 Survivability—Materiel TR 97–045 Camouflage, Concealment, and Deception TR 97–054 Virtual Reality TR 97–055 Live, Virtual, and Constructive Simulation Technologies TR 97–056 Synthetic Environment TR 97–057 Modeling and Simulation
Topography	TR 97–001 Command and Control TR 97–002 Situational Awareness TR 97–015 Common Terrain Portrayal EN 97–001 Develop Digital Terrain Data EN 97–002 Common Terrain Database Management
Current Battlespace Weather	TR 97–001 Command and Control TR 97–002 Situational Awareness TR 97–007 Battlefield Information Passage TR 97–012 Information Systems TR 97–020 Information Collection, Dissemination, and Analysis
Predicted Battlespace Weather	TR 97–002 Situational Awareness TR 97–040 Firepower Lethality TR 97–045 Camouflage, Concealment, and Deception TR 97–056 Synthetic Environment
Decision Aids	TR 97–002 Situational Awareness TR 97–003 Mission Planning and Rehearsal TR 97–016 Information Analysis TR 97–017 Information Display TR 97–018 Relevant Information and Intelligence TR 97–056 Synthetic Environment

N. HUMAN SYSTEMS INTERFACE

1. Scope

Army requirements on the individual combatant are increasing as never before as new technologies are being integrated into the soldier's role. The end of the cold war as well as societal and budgetary concerns have served to downsize our fighting forces. At the same time, night vision technologies allow us—and force us—to "own the night"; this also requires us to "staff" the night for round-the-clock operations. Technologies also allow us to increase the operating tempo of combat with faster, longer range weapons and vehicles such as a 45-miles per hour (mph) tank and the electronic corollary to "faster, longer," the digitized battlefield. Thus, our soldiers must work faster to engage fully the benefits of these technologies, and they must do so at more consistent and sustained peak levels, for there is no longer much time to ponder or to easily retrieve commands. This section is allied to the Human Systems Interface program in the DTAP, but the Army deals most critically with a variety of mission and environmental conditions not encountered by the other services or industry. The Human Systems Interface program encompasses information display and performance enhancement (ID&PE), design integration and supportability (DI&S), warrior protection and sustainment (WP&S), and personnel performance and training (PPT). The ID&PE and DI&S activities are presented here, while the WP&S and PPT research are discussed in Sections IV–F and IV–O, respectively. ID&PE and DI&S technologies seek to enhance the processing and delivery of task-critical information to individuals and groups, aiding the functional operation and logistical support of weapon and information systems, and the integration of crews with weapon systems for maximum mission effectiveness, survivability, and supportability.

2. Rationale

The key to force lethality, survivability, and unit efficiency is the effective use of human resources. People are the most critical component of weapon systems. They are also the most costly component. Personnel and related costs exceed $70 billion annually. There is an additional $20–30 billion spent on training, not all of which currently hits the mark. Part of the HSI mission is to lower this training burden while extending training effectiveness. This expenditure represents about 40 percent of the $241 billion FY97 defense budget. The Human Systems Interface S&T program directly contributes to all Joint Staff future warfighting capabilities by optimizing the use of the DoD's most critical resource—its people. The impacts of these technologies include:

- Substantial increases in unit readiness through lowered training requirements via optimized task, tool, and equipment redesign, as well as more robust training techniques where that training is most needed—while reducing costs.
- Improved mission performance—lethality *and* survivability—through more effective information displays and decision support systems.
- Casualty reduction from early warning, enhanced protection and escape systems.
- Enhanced mobility from better logistics, lowered physical requirements, and other troop sustainment technologies.

Combat systems will be designed to capitalize on human strengths and mitigate weaknesses while simultaneously improving sustainment and support of warfighting systems. Advances in warrior protection systems address concerns about casualties in conflict. By providing the personal protection and life support necessary to meet current and future threats, these technology efforts make the individual warrior more effective and achieve force multiplication. With fewer soldiers executing the mission, we decrease the tax burden and put fewer warfighters in harm's way while still achieving mission objectives. Advances in human systems interface technologies are essential for the services to meet their

global commitments in combat and peacekeeping roles.

Human Systems Interface technology takes a unique, multidisciplinary approach to the human role in combat operations. Our collective capability to draw on the physical, biological, biomedical, and behavioral sciences to support the core of human factors engineering S&T is more critical than ever. Instead of facing a single massive threat, the warfighter is also challenged by the potential of simultaneous, multiple, low-intensity conflicts. A force with new and larger weapon systems with increasing speed, range, and firepower is now joined by a smaller force with fewer weapon systems but with more functionality, fewer hands-on training hours, fewer people, less acquisition, and aging systems that must be maintained. This change in focus places a growing demand on the human, who is in the loop of every weapon system.

To achieve this, a more affordable, yet more broadly deployed, more "ready" force, the services must increasingly emphasize "force-multiplying" weapon systems and training and retention of qualified people and their personal protection, sustainment, and survival during operations. For the full range of weapon systems, Human Systems Interface technology is integral to major gains in operability, effectiveness, availability, and affordability. Over a weapon system's life cycle, the cost of the people to operate and maintain the system typically is significantly higher than the cost of the system's hardware. Through vigorous application of Human Systems Interface technologies to current and future weapon systems, we can achieve gains such as 50 percent reductions in average crew size, 25 percent reductions in physical, perceptual, and cognitive workloads, 15 percent or more reduction in the weight of personal equipment, 30 percent overall weight reduction in ballistic protection while decreasing casualties, doubling critical decision making accuracy and reliability, quadrupling overall crew member situation awareness, and achieving a 50 percent reduction in total life-cycle costs.

3. Technology Subareas

a. Information Display and Performance Enhancement

Goals and Timeframes

ID&PE aims to enhance soldier capabilities for both cognitive-perceptual and physical-physiological task demands. For the near term, in both cases the first tactic is to lower requirements through "human friendly" design of interfaces, tasks, and equipment. Extensive remapping of our understanding of these interactions is necessitated by the extremely rapid response needed to take advantage of force-multiplier technologies. Further, a good deal of work is needed to extrapolate beyond guidelines from the private sector and academia, where demands are not at militarily significant levels.

For the mid to far term, full-time, real-time situation awareness is the core challenge for cognitive S&T research. Information technology developments are critical to making available to the soldier the information potential lurking on the digitized battlefield of tomorrow. The primary route is through human engineering and integration of emerging sensor, display, and processor technologies to organize, identify, manage, and present critical combat data. Next, we must enhance mental performance via complementing human processing strengths and weaknesses, including lowering cognitive and perceptual demands under conditions of extreme physical demands and other stressors. Night vision devices, 3D auditory displays, and ergonomic design of tasks and tools will lead the way to enhanced performance for the 21st century soldier (see roadmap for timelines).

Major Technical Challenges

Challenges include presenting information (visual, aural, haptic) to the warfighter using robust displays that remain friendly even under combat stress conditions. Stressors range from those of jungle combat to those of rotorcraft warfare. New ways are needed to represent and visualize information extracted from the buzz and fog

of war. How to use multimodal control and input methods such as touch, speech, eye tracking, and natural language requires a serious S&T mentality.

A second challenge is to extend the soldier's physical, cognitive, and psychological capabilities. This involves a core human factors task—that of merging and extending existing models of biodynamics and ergonomics with emerging models of human cognition, decision making, and human stress. Once this is done, no time can be wasted in a transition to integration with weapon systems models, C^3I models, and realistic soldier-in-the-loop mission scenarios.

b. Design Integration and Supportability

Goals and Timeframes

The overarching objective here is to improve weapon system effectiveness, availability, and affordability throughout development, fielding, and life cycle. DI&S goals include:

- Developing a national (for selected aspects, international) technology base in human performance modeling and assessment.
- Designing tools and equipment for physical accommodation
- Devising efficient, robust methods for human error assessment, prediction, and avoidance.
- Developing tools, such as integrated manpower and personnel integration tools of integrated MANPRINT (IMPRINT) and individual unit solder simulation (IUSS), for estimating and evaluating human performance requirements for a given system design.
- Developing tools to both streamline and enhance the weapon system support infrastructure.

Major Technical Challenges

Earlier in this chapter, complexities brought about by emerging technologies was discussed. While the massive amount of human performance data collected over the past few decades could help reduce the effects of these complexities, the data are not always retrievable or transformable into in a form useful to efforts toward future human–system integration. A penalty is that the soldier's need often is addressed too late in the design and even fielding phases. Largely due to human variability, even linking the best of these data to CAD/computer-aided engineering (CAE) tools is considerably more difficult than when using data for physical systems.

New methods are needed to help share data among diverse disciplines and platforms, to extrapolate currently known human performance data into the 10–15 year future system, and to use the proper metrics for measuring progress.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for the Human Systems Interface is shown in Table IV–28.

5. Linkages to Future Operational Capabilities

The influence of this technology area on TRADOC FOCs is summarized in Table IV–29.

Table IV–28. Technical Objectives for Human Systems Interface

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Information Display and Performance Enhancement (ID&PE)	Context-sensitive intelligent interface Implement cognitive decision aiding tools in simulation use Develop algorithms to support commanders for on-the-move (OTM) operations Refinement of "audio icon" and integration in simulation platform Develop database of soldier clothing and equipment compatibility information Refine assessment techniques for national and international (joint coalition force) soldier modernization programs Establish reach, vision, and strength criteria for female crew Develop prognostic model of intelligence production and fusion Develop "precursor" performance metrics and markers for team unit	Indicators and warnings for dismounted soldiers Distributed interactive simulation for the individual soldier Command OTM controls and layouts Develop information engineering guidelines for information rich environments Develop flight and other symbologies for enhancing helmet-mounted displays (HMDs) Aiming accuracy, recoil mitigation, and indirect fire for small arms Strength augmentation and sensory enhancement Ergonomic design model for reducing soldier lift, carry, push, and pull loads Performance related model of injury–stress relationship For teleoperations, develop aids to provide textural and distance information, and to minimize attentional fixation	Multimodal interactive sensory displays Individual soldier simulation network (SIMNET) individual soldier's portal (I–PORT) 3D audio and video immersion displays 3D volumetric and immersion devices Tri-service commonality on performance aiding, system supportability, and design integration Develop human factors design guide for HMD Integrate personal performance enhancement of hardware and weapons Links to AI attributes, neural networks Release graphic soldier model with reach, vision, and strength database
Design Integration and Supportability (DI&S)	Human resource cost models relative to IEW, C^2 vehicle (C^2V) Integrate models and databases for human factors, manpower, personnel, and training (HMPT) Task performance models for expanded mission areas (C^2, maintenance, etc.) Evaluation of alternative system designs at notional system stage	Mission reconfigurable crew station Teleoperation crew station layout Full integration of generic algorithm for cockpit optimization (GASCO) into the man–machine integration design and analysis system (MIDAS) tool suite Simulation-based determination of training and system support concepts, requirements, and resources Database matrix for soldier system technologies for future system design evaluation HMPT analysis tradeoff tool for system redesign options	Integrated real-time and predictive system supportability and operational readiness assessment capability Full, synergistic, analysis capability from concept through prototype and from detailed interface specifications through force-on-force simulations Diagnostic links to system design, design costs, tactics, and training

Table IV–29. Human Systems Interface Linkages to Future Operational Capabilities

Technology Subarea	Integrated and Branch/Functional Unique Future Operational Capabilities
Information Display and Performance Enhancement (ID&PE)	TR 97–002 Situational Awareness TR 97–012 Information Systems TR 97–016 Information Analysis TR 97–018 Relevant Information and Intelligence TR 97–023 Mobility—Combat Dismounted TR 97–054 Virtual Reality TR 97–057 Modeling and Simulation
Design Integration and Supportability (DI&S)	TR 97–001 Command and Control TR 97–004 Tactical Operation Center Command Post TR 97–014 Hands-Free Equipment Operation TR 97–018 Relevant Information and Intelligence TR 97–048 Performance Support Systems TR 97–053 Embedded Training and Soldier–Machine Interface TR 97–057 Modeling and Simulation

O. PERSONNEL PERFORMANCE AND TRAINING

1. Scope

The DoD Personnel Performance and Training (PP&T) program seeks to maximize human military performance. Army S&T investments in personnel performance technology address recruitment, selection, classification, and assignment of people to military jobs. These investments seek to reduce the attrition of high quality personnel, support the development of managers and leaders, and predict and measure the consequences of policy decisions. Army S&T investments in training technology improve the effectiveness of individual and collective training, enhance military training systems, and provide more cost-effective opportunities for skill practice, mission rehearsal, and enhanced performance. PP&T technologies provide efficiencies in the operation and maintenance of both current and future systems and result in increased readiness of our warfighting forces.

2. Rationale

The FY98 Army posture statement states:

> *"The Army's ability to respond rapidly to crises worldwide requires a trained and ready Army, and that requires high-quality people; tough, realistic, mission-focused training, and competent leaders . . . . Executing missions across the full spectrum of military operations requires soldiers able to think on both a tactical and an operational level. They must be highly skilled and well trained to adapt to complex, dangerous, and ever changing situations throughout the world. [Leaders] must be creative at solving problems and capable of operating in complex, ambiguous, ever-changing environments."*

Force XXI will enhance the abilities of the best soldiers in the Army's history through the use of simulations and simulator-based training. As they have always been, soldiers will be the most important element of Force XXI.

Intelligent selection, classification, retention, and organization of quality soldiers are necessary to maintain a stable, disciplined, well-trained fighting force. Effective individual and unit collective training strategies must be developed to meet the Army's changing roles and missions in the face of decreased resources. Significant advances in distributed interactive simulation (DIS) and virtual reality (VR) technologies permit the development of synthetic environments that can be used to provide realistic combat training. Empirically based training strategies are required to make the most cost-effective use of new training technologies.

3. Technology Subareas

a. Personnel Performance

Goals and Timeframes

Selection and Classification. Improved aptitude testing and assignment methods reduce training time and increase the quality of soldier performance. Applying these technologies to the *Army After Next* requires knowing what tasks 21st century noncommissioned officers (NCOs) will be performing and hence what characteristics they must possess to become proficient and effective in these jobs. The near-term research tasks include identifying future NCO requirements (FY98), developing prototype NCO performance measures (FY99), and linking aptitude and performance measures (FY00).

Human Resource Development. This research will use new longitudinal investigative methods to determine the effects on soldiers and families of participation in significant Army organizational changes/events (e.g., reserve component participation in the recent Bosnia peacekeeping mission, the Gulf War, Army downsizing, and various stability operations). Short- and long-term lessons learned from these experiences will be provided to the Army in FY98.

Major Technical Challenges

- Develop ways of capturing what future NCO jobs will demand in terms of individual attributes and skills, and develop measures that best predict which individuals should be selected for these new jobs.

- Develop techniques for DoD and Army decision makers, unit commanders, soldiers, and their families to effectively adapt to organizational change and demands.

b. Training

Goals and Timeframes

Unit Collective Training. The effectiveness of synthetic and DIS environments rests in large measure on the training strategies, performance measurement techniques, and performance feedback methods employed. Research goals are to develop training packages and evaluation techniques to support emerging Force XXI digital capabilities; specify the required simulation capabilities and the effective mix of live exercises with new and existing training aids, devices, simulators, and simulations (FY98); determine training needs for mission planning and mission rehearsal tasks (FY98); and develop measures to assess performance and provide feedback for DIS systems such as the close combat tactical trainer (FY98). In support of the mounted battlespace battle laboratory, develop training and evaluation technologies that will prepare operators and commanders to take maximum advantage of evolving digital C^3 systems (FY01).

Simulator Enhanced Training. This research uses a simulator training research advanced testbed for aviation (STRATA) to evaluate all significant parameters of simulator design to determine their contribution to the development and retention of aviation skills. In FY98 the types and direction of motion needed for effective simulation-based training will be determined.

Land Warfare Training. Research goals include development of night operations training support packages for infantry forces, a computer-based foreign language tutoring system for soldiers who need to sustain high levels of language proficiency, and decision making tools to help reserve component (RC) commanders decide when it is more cost effective to do live training or a given form of simulation. Expected FY98 products include training programs for improving combat vehicle identification with IR devices, validated training materials for selected battle staff positions, continuous speech recognition incorporated in the language tutor, and methods for training and assessing individual team member skills in virtual environments (VEs).

Battle Command Training. Future battle scenarios place a premium on commanders who are versatile in their thinking, able to synthesize large amounts of disparate data, and able to change their actions quickly if the situation requires it. The research tasks include developing measures of battle command skills (FY98), validating these skill measures (FY99), and tryout of instructional modules for teaching versatile thinking skills (FY00).

Major Technical Challenges

The Army needs to develop new training and performance measurement technology that will allow it to effectively train for the full range of individual and unit tasks within budgetary constraints. Research is needed to enhance the effectiveness of new training simulation technologies such as VE and DIS through the development of training strategies. Research has shown that the effectiveness of new training aids, devices, simulators, and simulations (TADSS) is largely a function of their appropriateness to the tasks that they train for, and the adequacy of performance measurement and feedback techniques. Innovative training methods need to be developed that use these new tools to improve overall training effectiveness. Specific challenges include:

- Develop individual and collective training strategies that provide an effective and affordable mix of live exercises and synthetic training environments to prepare soldiers to cope with the proliferation of possible missions.
- Assess the effectiveness of VE, DIS, and TADSS systems to support individual, unit collective, multiservice, and joint

training and use the data to maximize training value.

- Demonstrate training strategies and performance evaluation technologies to support emerging digital technologies and the accompanying new doctrine.
- Increase knowledge of what the future battle commander's critical thinking skills will be, and how to improve their acquisition through instruction.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Personnel Performance and Training is shown in Table IV–30.

5. Linkages to Future Operational Capabilities

The influence of this technology area on TRADOC FOCs is summarized in Table IV–31.

Table IV–30. Technical Objectives for Personnel Performance and Training

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Personnel Performance	Identify Force XXI NCO job requirements Post-mobilization impact of peacekeeping operations on career development and commitment	New assessment techniques for NCO selection, assignment, and development Tools to evaluate soldier/family impact of changing military experiences	Job-specific selection and assignment methods that ensure flexible and effective personnel/job/career matching Organization and job design/redesign methods that keep pace with changing missions and skill requirements
Training	Prototype training methods/strategies to facilitate the acquisition of collective skills in a digital environment Fidelity requirements for networked aviation training systems Methodologies for training and assessing small dismounted unit performance in a virtual environment (VE) Measures to assess battle command skill performance	Combined arms, multiservice, and joint training methods and measures of performance Aviation training strategy utilizing low cost alternatives to resource-intensive training Prototype training and evaluation methods to support emerging digital equipment and doctrine Interactive, VE-based training and mission rehearsal techniques for soldiers and small units Methods for improving the acquisition and use of cognitive skills needed for 21st century battle command	Training techniques and strategies for warfighters to attain mastery of critical tasks and skills in synthetic environments Methods for developing commanders of a more diversified military force to respond effectively and rapidly to future mission requirements Advanced warfighting training strategies for units to attain 21st century battlefield dominance Advanced, cost-effective training methods and strategies for the RC to effectively perform its changing and complex roles and missions

Table IV–31. Personnel Performance and Training Linkages to Future Operational Capabilities

Technology Subarea	Integrated and Branch/Functional Unique Future Operational Capabilities
Personnel Performance	TR 97–047 Leader and Commander Training TR 97–051 Training Infrastructure
Training	TR 97–047 Leader and Commander Training TR 97–048 Performance Support Systems TR 97–049 Battle Staff Training and Support TR 97–050 Joint, Combined, and Interagency Training TR 97–052 Training Aids, Devices, Simulators, and Simulations Fidelity Requirements TR 97–054 Virtual Reality TR 97–055 Live, Virtual, and Constructive Simulation Technologies TR 97–056 Synthetic Environment

P. MATERIALS, PROCESSES, AND STRUCTURES

1. Scope

The Army's materials, processes, and structures (MP&S) program provides enabling technologies that are used to construct every physical system or device that the Army uses. The MP&S program provides Army-unique technology solutions and options that will increase the level of lethality and survivability performance and improve mobility, transportability and durability while reducing the maintenance burden and life-cycle costs of all Army systems.

The materials subarea focuses on providing materials with the superior properties required for use in structural, optical, armor, and armament, chemical and biological (CB) warfare and laser protection, biomedical, and Army infrastructure applications. All classes of materials are included: metals, ceramics, polymers, composites of all types, coatings, energetic, semi- and super-conductor, and electromagnetic functional materials. Meeting the performance needs of future Army systems will require synthesis of new materials, modification of existing materials, design of property specific microstructures and composite architectures, and development of advanced modeling and characterization techniques for specific microstructures, properties, and both quasi-static and dynamic degradation and damage modes.

The materials processing subarea includes those technologies by which raw or precursor materials are transformed into affordable monolithic or engineered materials and/or components with the requisite properties and reliability for Army utilization. Included in the processing subarea are such technologies as casting, rolling, extrusion, cold and hot isostatic pressing, hot pressing, furnace sintering of metal or ceramic powders, laser sintering of titanium, polymerization, filament winding, composite processing and curing, joining, machining, and chemical vapor deposition. Also, lower substrate temperature coating processes are being developed, including ion beam assisted deposition (IBAD), pulsed laser deposition (PLD), and other surface modification technologies.

Process modeling and control and the development of new processing techniques for the manufacturing of multifunctional material systems will simultaneously improve quality and reduce costs of future Army materiel. Under the new paradigm of "intelligent processing," quantitative process models, AI/expert systems, embedded sensors, intentionally inhomogeneous compositional and microstructural gradients for localized property modification, and feedback/feedforward control systems are coupled so that processes can be adjusted in real time. Closely allied to "intelligent processing" are online nondestructive testing and inspection technologies, which enhance quality and durability.

The structures subarea is aimed at demonstrating generic structures based on advanced materials and processes that meet Army specific needs, such as structural elements for armored vehicles and helicopters, guns and ammunition, and missile/smart projectiles. Particular emphasis is on the development and modification of design tools and modeling for failure, fatigue, and life prediction analysis.

2. Rationale

All Army hardware critically depends on MP&S for its performance, affordability, and durability. To the maximum extent possible, the Army relies on improvements of existing MP&S capabilities in industry, academia, and the other services. However, the many unique Army requirements, such as thick-section ballistically efficient composite structures for combat vehicles, combat helicopter structures, CB and laser protective materials, antiarmor munitions, transparent and opaque armor materials, do not have commercial markets that support an adequate private sector R&D infrastructure. Further, there is no commercial analogue that super-

imposes both the severe environments and sustained high-stress use to which materials are subjected on the modern battlefield. Thus, a robust in-house MP&S technology generation program is essential to sustain the Army's current and especially its future warfighting edge. A soldier-responsive in-house R&D combat operating environment (COE) with a critical mass of dedicated experts is essential to focus and manage the creation, evaluation, and transition of both external and internal MP&S technology advances to address Army specific requirements.

3. Technology Subareas

a. Materials

Goals and Timeframes

New materials with greatly improved properties and durability are being developed that enable major capability improvements for Army systems. For example, entirely new polymer matrix composite material concepts that are being developed for reducing armor weight by 35 to 45 percent will also dramatically improve ballistic performance and reduce overall systems costs. This weight reduction development will have a significant impact on increasing air deployment capability. Further opportunities arise from the multifunctional capabilities of composite material systems, whereby structural, ballistic, and signature reduction improvements can be incorporated simultaneously into one system.

Advanced ceramics are under development for both opaque and transparent armor ceramic applications as well as for missile guidance domes and windows. Transparent spinel ceramics, other glass-ceramics, and polymers are being developed to demonstrate superior ballistic properties for soldier systems application in FY99 under STO IV.P.05. Also, the characterization and evaluation of opaque ceramics under lateral and axial constraint are under investigation to improve their capability for interface defeat of high velocity impacting projectiles (see Figure IV–14). By FY04, advanced armor ceramics having improved penetration resistance with confinement will be demonstrated for larger scale projectiles at velocities above 2,000 meters per second (m/s). Opaque ultra light ballistically resistant personnel armor materials are being developed under STO IV.P.04 for FY99. Recent advances in converting highly ordered polymers into textile fibers with outstanding strength-to-weight ratios will lead to lighter weight body

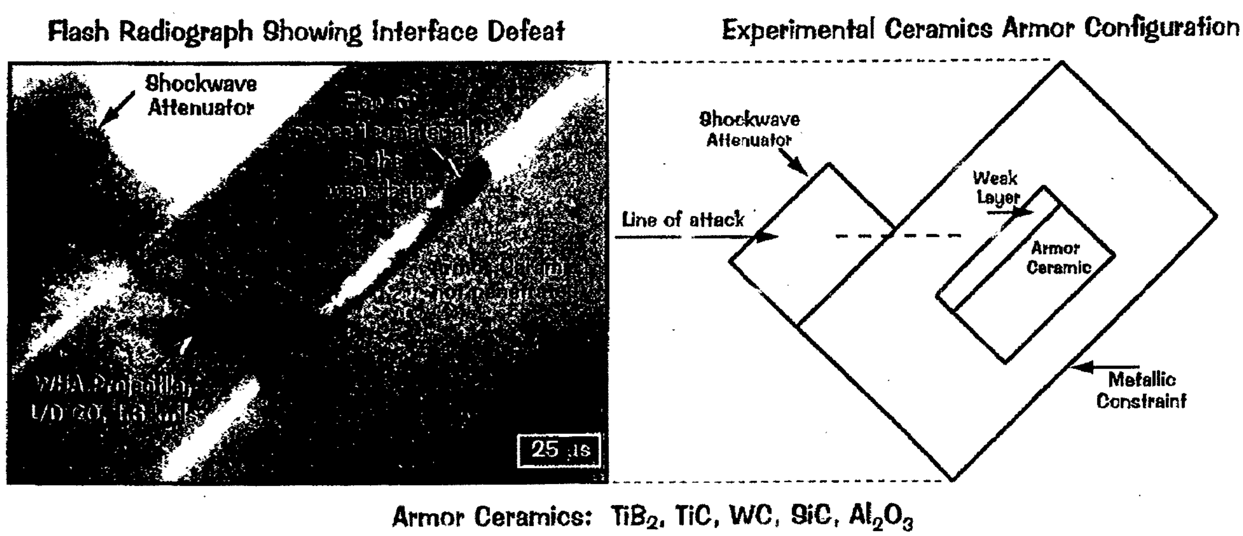


Figure IV–14. Interface Defeat of Long-Rod Projectiles by Constrained Armor Ceramics

armor, helmets, and shelters without reducing ballistic protection (see Section IV–F). Computer-aided design (CAD) of the molecular structure of polymers will be utilized to develop improved transparent armor and controlled permeability barrier materials for protection against chemical and biological agents by FY98.

Weldability and the evaluation of mechanical and ballistic properties of low-cost titanium alloys (with higher interstitial content) are being pursued for appreciable weight reductions over conventional aluminum and steel alloys for ground vehicle applications. Higher performance heavy alloys for penetrators and shaped charge warheads are essential to defeat advanced armor systems. The goals include a full-sized tungsten penetrator with equal performance to depleted uranium by FY03 and replacement of copper shaped charge liners by FY05. Issues related to the development of advanced warhead materials are discussed in Section IV–I. Improved ceramic thermal barrier coatings, wear resistant coatings, and monolithic and reinforced ceramics composites for rotorcraft and ground vehicle propulsion (see Sections IV–C and IV–S) will be demonstrated in the FY98–02 timeframe. Wear resistant coatings and advanced composite materials with tailored combinations of mechanical and physical properties for reducing weight and improving durability of both conventional armaments and electric guns will be demonstrated by FY98 (see Section IV–I).

Major Technical Challenges

While the field of materials science and engineering has made dramatic advances in materials performance, many formidable scientific and technological problems still exist. Of particular importance to the Army is the ability to transition the state-of-the-art knowledge base of composition–microstructure property parameters to models that predict the behavior of materials in such complex phenomena as ballistic penetration and defeat, detonation kinetics, environmental degradation, and chemical agent permeation. Specific technical challenges include:

- Develop and validate models to predict the static and dynamic behavior of fiber/matrix interfaces for improved synthesis and performance of polymer and/or inorganic matrix composite structural materials.
- Develop and validate predictive models for the environmental durability of monolithic and composite materials. Develop and validate improved models for the interactions of gases, vapors, and liquids with polymeric barrier materials.
- Design opaque and transparent ceramics microstructures that will provide superior ballistic performance with improved mass and space efficiencies. Develop cost-efficient lightweight transparent armor ceramics and polymers for personnel and sensor protection.
- Design tungsten or other heavy metal alloys/microstructures that will provide equal ballistic performance to depleted uranium, and improvements over copper shaped charge liners.
- Develop high strength steels and titanium alloys with improved ballistic properties that also maintain toughness, weldability, affordability, and stress corrosion cracking resistance.
- Develop improved materials for protection from agile laser threats for the individual soldier and direct view optics. Also, improved nonlinear optical materials for sensor protection devices.
- Reduce wear and erosion in structural and functional materials for armament and vehicle components. Model and mitigate the micromechanical failure mechanisms in elastomeric materials for tank track application.

b. Processes

Goals and Timeframes

The MP&S program thrusts in processing S&T focus on those processes that are required to

implement the incorporation of advanced materials in Army systems. Thick section composite processing presents unique challenges not encountered in traditionally thin structures. Process simulation models are being developed that couple the effects of thermochemical and thermomechanical interactions and incorporate micromechanical models to accommodate complex fiber/fabric architectures are required (see Figure IV–15). New technologies such as coinjection resin transfer molding provide improved properties while reducing manufacturing costs of multifunctional integrated armor systems under development. These will be transitioned to the Tank–Automotive Research, Development, and Engineering Center (TARDEC) during FY98.

Improved process control methodologies including neural net feedback/feedforward capabilities, will be demonstrated in FY98–99 and will transition to the Composite Armored Vehicle (CAV) ATD and follow-on programs. Integration of the sensor mounted as roving thread (SMART) weave process into manufacturing systems is covered in Section IV–T. Processing thrusts to develop low-cost titanium alloys for lightweight armor and weapon systems such as howitzers, with enhanced air mobility, will be demonstrated by FY98. Lower temperature and lower cost ceramic processing approaches are being developed to improve the affordability and availability of advanced transparent and opaque armor ceramic materials. Properties and tape casting process optimization for recently developed high performance barium strontium titanate ferroelectric materials are being refined that will enable size, weight, and cost reductions for a new generation of microwave phased shifters at 35 GHz. This technology will transition to CECOM in FY05.

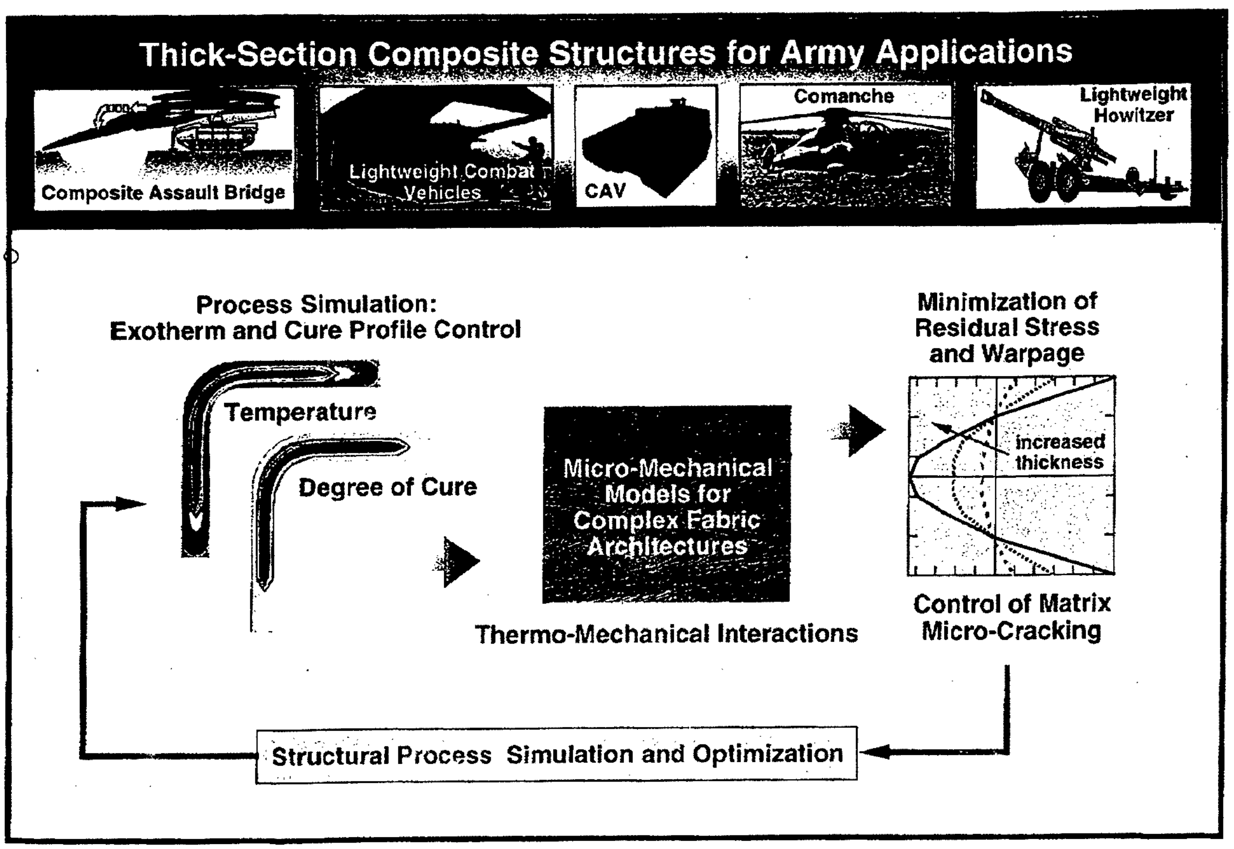


Figure IV–15. Process Simulation Methodology for Thick Section Composite Structures

Major Technical Challenges

Much progress has been made in modeling single processes and process steps. However, the integration of real-time, noncontact, or online sensing (especially at the very high temperatures required in metal and ceramic processing) with adaptive control technology for the vast array of materials processes used by the Army is a formidable challenge. Specific challenges include:

- Develop and validate knowledge-based models for consolidation synthesis, post-consolidation thermal or thermomechanical processing, and improved capability for joining or repair of polymers, ceramics, metals, and organic and inorganic matrix composites.
- Develop opaque and transparent ceramic processing models for improved affordability and impact damage tolerance performance. Develop consolidation processing techniques for nano-size ceramic and metallic particulates.
- Develop process-specific sensors and control systems.
- Develop new materials processing or surface modification to achieve near or actual net shape components of complex geometry and variable composition and microstructure combinations to yield significantly improved tribological or structural performance in more affordable materials/design systems.

c. Structures

Goals and Timeframes

The structures portion of MP&S technology focuses on developing structures with a high level of structural integrity that are inspectable, analyzable, and survivable in the harsh combat environment. To be cost effective, the structural design must integrate advanced structural design concepts that are compatible with mass production manufacturing technologies. These structures can be man-rated or unmanned air or ground vehicles and hence must be designed to specific vibration and noise levels to maintain crew comfort and a low noise signature.

The technological efforts have led to improved methodologies for detecting and predicting the onset and growth of internal damage in composite structures. This has resulted in lighter weight, more durable structures. In the advanced concepts area, conceptual composite vehicle structures that integrate both ballistic protection and structural support are being evaluated (see Figure IV–16). Such integral composite structures offer significant improvements in weight and noise reduction, as well as the additional potential for the integration of other multifunctional attributes. Additionally, composite structures in rotating pulsed power systems (Figure IV–17) provide distinct weight and other design advantages. The application of smart materials to control sound transmission through a structure has been demonstrated on fuselage-like shell structures fabricated from composite materials. Reducing interior noise levels greatly improves crew comfort and reduces occupant fatigue levels.

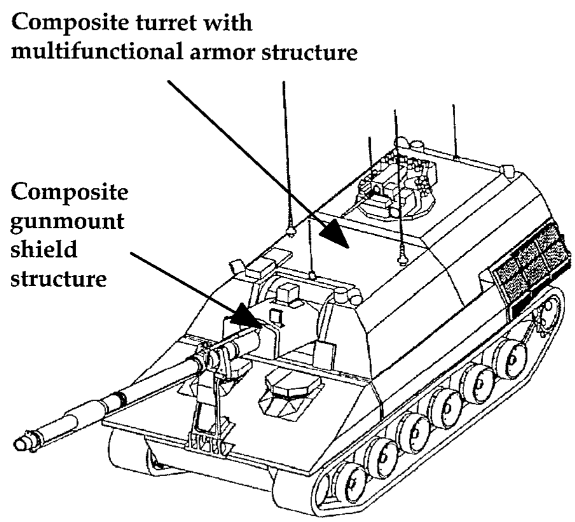


Figure IV–16. Composite Structures for Crusader Concept

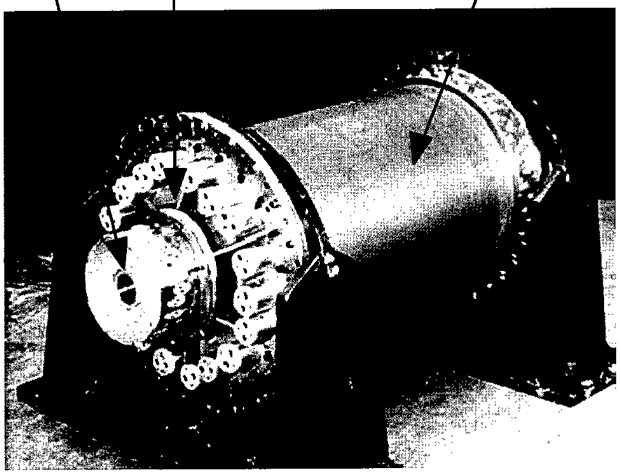


Figure IV–17. Composite-Based Pulsed Alternator Structure for Electromagnetic Gun

Major Technical Challenges

- Design structurally efficient, cost-effective, and durable composite structures for Army unique ground and air vehicles as well as other structural applications, including troop support and ordnance.
- Develop fracture mechanics methodologies, low-cycle fatigue, and stress analyses suited to meet Army structural needs.
- Develop nondestructive evaluation (NDE) techniques and affordable in-situ sensors for identification and quantification of defects and anomalies in composite structures.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Materials, Processes, and Structures is shown in Table IV–32.

5. Linkages to Future Operational Capabilities

The influence of this technology area on TRADOC FOCs is summarized in Table IV–33.

Table IV–32. Technical Objectives for Materials, Processes, and Structures

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Materials	Armor ceramics evaluated in interface projectile defeat Ultra-lightweight, ballistically-resistant materials Low cost, 20 GHz ferroelectrics Low cost titanium alloy transitioned to TACOM Multiplane damage detection of composite laminates	Ceramic process/defects evaluated for interface defeat Ceramic thermal barrier coating for Army propulsion 28–35 GHz materials database Tungsten-based, long-rod kinetic-energy (KE) penetrators 25% cost reduction in organic composite structures	Confined armor ceramics transitioned to user High temperature polymers (>400°C) 35 GHz materials for phased array antennas Tungsten shaped charge liners Thin film microwave materials
Processes	Transparent armor prototype Scaleup of Si diamond-like carbon (DLC) coatings Laser processed titanium plate Co-injection RTM of multifunctional integral armor Organic (polymer) matrix composite (OMC) and carbon-carbon (C–C) composites for the Ballistic Missile Defense Organization (BMDO)	Transparent spinel scale up Consolidation of metal and ceramic nanopowders Continuous process for insensitive propellants RTM processing with embedded sensors	Transparent, low-cost aluminum oxynitride (ALON) Electron beam curing of large organic composites Continuous process for insensitive explosives Affordable rapid prototyping with inorganics

Table IV–32. Technical Objectives for Materials, Processes, and Structures (continued)

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Structures	Composite rotor blades Energy absorbing structure Constitutive behavior of rocket propellants at interior ballistic rates. Lightweight, low-cost structural concepts	Demonstrate user defined composite structure Multifunctional armor for active protection (AP), overhead, and mineblast Pulsed power storage device Case-bonded gun launched rocket motor designs	Composites with embedded actuators and active sound cancellation. Controls and airframe for gun launched projectiles Lightweight rail gun structures

Table IV–33. Materials, Processes, and Structures Linkages to Future Operational Capabilities

Technology Subarea	Integrated and Branch/Functional Unique Future Operational Capabilities
Materials	TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–022 Mobility—Combat Mounted TR 97–037 Combat Vehicle Propulsion TR 97–040 Firepower Lethality TR 97–043 Survivability—Materiel TR 97–044 Survivability—Personnel
Processes	TR 97–022 Mobility—Combat Mounted TR 97–030 Sustainment Maintenance TR 97–040 Firepower Lethality TR 97–043 Survivability—Materiel TR 97–044 Survivability—Personnel TR 97–045 Camouflage, Concealment, and Deception
Structures	TR 97–022 Mobility—Combat Mounted TR 97–023 Mobility—Combat Dismounted TR 97–035 Power Source and Accessories TR 97–040 Firepower Lethality TR 97–043 Survivability—Materiel

Q. MEDICAL AND BIOMEDICAL SCIENCE AND TECHNOLOGY

1. Scope

Military Medical and Biomedical Science and Technology programs are a unique national resource focused to yield superior capabilities for medical support and services to U.S. armed forces. Unlike other national and international medical and biomedical S&T investments, military research is concerned with preserving the combatant's health and optimizing mission capabilities despite extraordinary battle, nonbattle, and disease threats. It is also unlike most of the more widely visible Army modernization programs because its technology is incorporated in service men and women rather than into the systems they use. This technology area is vital to the human capability dimension of all joint warfighting capabilities. Weapon system developers exploit capabilities to mitigate system hazards, improve soldier survivability, and optimize operator-system interfaces. Because of its special and unique nature, international treaties and conventions require military medical research to be conducted for the benefit of mankind. Additionally, many activities and products are regulated by the U.S. Food and Drug Administration (FDA).

The Army Medical and Biomedical S&T Program is divided into four technology subareas: infectious diseases of military importance; medical, chemical, and biological defense; Army operational medicine, and combat casualty care. Each subarea focuses on a specific category of threat to the health and performance of soldiers. The first three technology subareas emphasize the prevention of battle and nonbattle injury and disease while the combat casualty care research program emphasizes far-forward treatment. All three prevention research programs provide both medical materiel (e.g., vaccines, drugs, and applied medical systems) and biomedical information. Combat casualty care provides medical and surgical capabilities tailored to military medical needs for resuscitation, stabilization, evacuation, and treatment of all battle and nonbattle casualties. Each technology subarea has objectives that respond to the national military strategy.

The National Defense Act of Fiscal Year 1994 (Public Law 103–160) consolidated CBD programs, including both nonmedical and medical, under the management of OSD, with the Army serving as executive agent. The medical CBD programs are discussed here; the nonmedical CBD programs are addressed in Section IV–E.

2. Rationale

Individual service men and women are the most important, and the most vulnerable, components of military systems and mission capabilities. Disease and nonbattle injury typically far outweigh battle-related injury as the greatest cause of casualties among military forces. Regional, life-threatening, or incapacitating disease epidemics both limit and constrain military deployment alternatives. Widespread sickness and injury are mission aborting; high casualty and death rates are warstoppers. Post-deployment health problems have an adverse impact on future capabilities and on CONUS forces. The current force structure is confronted with an expanded potential for large-scale regional conflicts, proliferation of WMDs, and ready availability of advanced conventional weapons, as well as more diverse and highly complex missions characterized by continuous, high-tempo operations. These more dangerous challenges are coupled with enduring threats of disease, harsh climates, operational stress, and injury. These realities mandate a sustained commitment to robust investment in medical research programs (Figure IV–18).

3. Technology Subareas

a. Infectious Diseases of Military Importance

Goals and Timeframes

The goals of the military infectious disease research program are primarily to sustain force

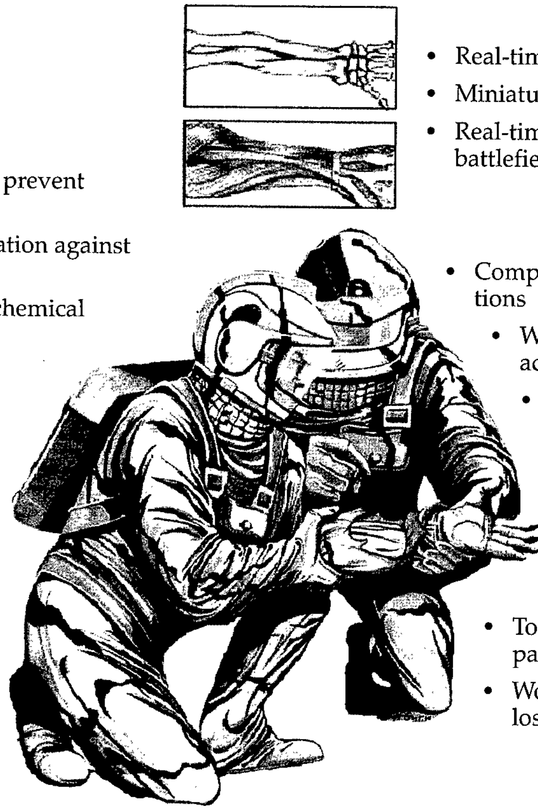


Figure IV–18. Future Medical Technologies

structure by protecting soldiers from incapacitating infectious diseases through the development of vaccines and disease-preventing drugs, and secondarily to develop effective drug treatments to rapidly return personnel to duty. Infectious diseases pose a significant threat to operational effectiveness. Most Americans lack immunity to diseases that are endemic abroad. Prevention of epidemic infections in forces deployed abroad is a force multiplier that enables maximal global operational capability. Immunization prior to deployment is the preferable medical countermeasure to infection because it adds to the full dimensional protection of our forces and supports focused logistics by reducing logistical requirements in the theater of operations. In lieu of available vaccines, a strong program in chemoprophylaxis addresses ongoing needs and the potential emergence of biological resistance to current and future protective systems. The continuing surveillance for new and emerging infectious diseases by the infectious disease research program allows information superiority and tailored, theater-specific interventions resulting in sustainment of the force. Of major importance to the military are the parasitic diseases malaria and leishmaniasis; the bacterial diseases responsible for diarrhea (i.e., *Shigella*, enterotoxigenic *Escherichia coli* (ETEC), Campylobacter), and the viral disease, dengue fever. The program also develops improved materiel for control of arthropod disease-vectors and addresses a variety of other threats to mobilizing and deployed forces, including hepatitis, meningitis, viral encephalitis, hemorrhagic fevers and infection with the human immunodeficiency virus (HIV).

A variety of new antimalarial drugs will replace drugs rendered ineffective by the development of parasite resistance for treatment of multidrug resistant malaria and prophylaxis (transition to advanced development in

FY01–03). Vaccines to provide protection against Falciparum malaria (FY00) and Vivax malaria (FY02) are currently under development, and a combined vaccine against both (FY08) will be assessed. Vaccines soon-to-be transitioned against *Shigella sonnei, Shigella flexneri* (FY99), and *Shigella dysenteriae* (FY01) will provide protection against the major agents causing dysentery. Vaccines against Campylobacter (FY99) and ETEC (FY01) will provide additional protection against the major causes of watery diarrhea. The feasibility of a combined, oral microencapsulated vaccine for major diarrheal threats will be assessed (FY08). A prototype tetravalent dengue vaccine is currently being developed (FY01). New forward deployable diagnostic test (FDDT) systems are under development using current and new technologies. Technology is being developed to transition antibody-based, "dipstick" diagnostic tests for vector-borne diseases and enteric infections (FY99). PCR microchip systems are also being explored (FY06).

Major Technical Challenges

There is a constant stream of emerging diseases. It is estimated that one disease of potential military importance is identified each year, while diseases that previously had been treated successfully develop resistance to formerly effective drugs. The focus of market-driven pharmaceutical development is on diseases important in the industrialized world, not on infectious diseases prominent in many strategically significant areas where U.S. military forces might often deploy. Thus, fundamental insight into the biology of the infectious organism and human response to infection must be developed through Army-supported research. Drug and vaccine development requires the use of animal models of human infection to validate their efficacy. In many cases, such as malaria, the species of parasite that will infect laboratory animals is not the same as that afflicting humans. Furthermore, the manifestations of the disease in an animal model may not reflect those seen in human disease. Therefore, other correlates of disease such as in vitro models need to be developed and used. To obtain sufficient quantities of a pathogen for study, methods need to be developed to expand the agent, either in vitro or in vivo.

Some specific technical challenges for diseases of prime military importance are presented below:

- Animal and laboratory models for parasitic threats are not good predictors in drug studies.
- Knowledge of parasite biology and mechanisms of drug resistance is incomplete.
- Drug discovery and design are time consuming and costly.
- The full range of antigens involved in protection from most pathogens is unknown.
- Informative animal models for malarial, diarrheal, and viral diseases are needed.
- New approaches to enhance the mucosal immune response must be developed.
- The technology to combine potentially incompatible vaccine formulations and dosing regimens into a single, combined vaccine for diarrheal or malarial agents, or a tetravalent dengue vaccine, must be developed.
- Appropriate field sites to test vaccines for efficacy in humans need to be identified.
- The best vaccine technology for a particular threat must be identified and selected.
- Diagnostic assays have insufficient sensitivity to detect pathogens at the time of clinical presentation.
- Diversity of etiologic agents of disease makes no single diagnostic platform appropriate for all diseases.

b. Medical Chemical and Biological Defense

Goals and Timeframes

The primary goal of the Medical Chemical and Biological Defense Research Programs (MCBDRPs) is to ensure the sustained effective-

ness of U.S. armed forces operating in a CBW environment by the timely provision of medical countermeasures. This goal is accomplished by the use of prophylactic medical countermeasures (e.g., vaccine and pretreatment drugs), by enhanced therapeutic countermeasures (antisera and improved chemotherapeutics) and by improved CB diagnostic capabilities far-forward. Improvements in these medical countermeasures will maximize return to duty.

Goals within the medical chemical defense area are as follows:

- By FY99, develop biotechnology-based chemical agent prophylaxes that provide protection against battlefield concentrations of chemical warfare (CW) agents without operationally significant physiological or psychological side effects.
- By FY99, demonstrate safety and efficacy sufficient for a Milestone 0 transition of a reactive topical skin protectant (providing protection against penetration) that will detoxify both vesicant and nerve agents.
- By FY00, demonstrate safety and efficacy of a candidate medical countermeasure against vesicant agents sufficient for a Milestone 0 transition decision.
- By FY02, demonstrate safety and efficacy sufficient for a Milestone 0 transition decision of an advanced skin/wound decontamination system for decontaminating chemically contaminated wounds.

Within the medical biological defense area, vaccines are being developed that will protect at least 80 percent of the immunized personnel against an aerosol challenge and will induce minimum reactogenicity in soldiers when immunized. Safety and efficacy in preclinical studies using animal models will be demonstrated for the following vaccines: second generation botulinum toxin vaccine (FY98), second-generation plague vaccine (FY98), encephalomyelitis vaccines (FY98), brucellosis vaccine (FY99), ricin vaccine (FY00), staphylococcal enterotoxin B vaccine (FY00), and multiagent vaccines for biological threat agents (FY02). After these successful transition milestones, initial clinical trials will be conducted.

Major Technical Challenges

The development of new drugs and vaccines for a particular chemical or biological threat agent requires both close examination of the threat agent to determine the toxicologic or pathogenic mechanisms of the agent or disease, and the development of appropriate pharmacologic or vaccine strategies to counteract these mechanisms. Strategies for vaccine development must embrace new knowledge regarding the human immune system. This includes information about generation of immunity, the preservation of immunological memory, and the regulation or modulation of immune functions, including enhancement and suppression. Similarly, new pharmacological products exploit new knowledge regarding biochemical and pathophysiological mechanisms associated with toxic cell death and organ failure.

New candidate drugs and vaccines must be both safe and efficacious. These criteria are regulated by the FDA. Ethically it is not possible to conduct tests in humans of the efficacy of chemical agent prophylaxes or treatments, nor can biological warfare vaccines be evaluated in this manner. Extensive safety and immunogenicity studies are, however, conducted in these development programs. Efficacy testing must be conducted in model systems. Animal models do not currently exist for many of the CB agents. The use of existing animal models is also limited by the desire to decrease or eliminate the use of animals for drug and vaccine development.

Specific technical challenges include:

- Developing appropriate animal models to test the safety and efficacy of medical countermeasures predictive of human safety and efficacy.

- Increasing genetic and biologic information applicable to medical countermeasures against threat agents.
- Developing pretreatments/antidotes with special characteristics (e.g., quick acting, long acting, easy to carry/use).
- Exploiting the human immune system to provide protection against threat agents.
- Analyzing new vaccine delivery systems and multi-agent vaccines.
- Synthesizing reactive/catalytic decontaminants and demonstrating that decontaminants and protective compounds are safe.

c. Army Operational Medicine

Goals and Timeframes

The goals of the Army operational medicine research program are to protect soldiers from environmental injury and materiel/system hazards; shape medically sound safety and design criteria for military systems; sustain individual and unit health and performance under operational stresses, especially continuous and sustained operations (CONOPS/SUSOPS), and quantify performance criteria and soldier effectiveness to improve operational concepts and doctrine.

The modern warfighter will require the full range of human physical and mental capability to survive and prevail in future military operations. Goals are:

- By FY99, establish medical criteria to optimize efficiency and ensure safety of individual soldier equipment (combat boots, body armor, load carriage systems) for use by the equipment developers. Develop state-of-the-art scientifically based training programs to improve performance of elite units for special occupational requirements, and to increase opportunities of all soldiers in jobs with specific physical standards.
- By FY98, operationally test melatonin, a hormone that acts as a master synchronizer of body rhythms and as a natural sleep inducer for ability to prevent symptoms of jet lag and fatigue in soldiers deploying across time zones and in night operations. Specific physical and psychological training strategies will be developed to harden selected individuals to operate continuously without performance deficit or injury for 72 hours.
- By FY99, conduct a continuous operations simulation to demonstrate and refine the sleep-induction/rapid reawakening and stimulant components of the sleep management system.
- By FY99, identify a rapid, reliable, and inexpensive means for assessing a soldier's level of mental fatigue and alertness. Develop and demonstrate a wrist-worn sleep/activity monitor with an integrated microprocessor system.
- By FY98, integrate real-time satellite-derived weather data into thermal strain decision aids for battlefield commanders. The MERCURY model system of environmental hazards will predict soldier performance in specific real-time locations.
- By FY99, connect a sensor suite of technologies such as accelerometry, ausculation, spectroscopy, electrical impedance, and force and temperature sensing through a wireless body local area network system, with remote passive data interrogation capabilities.
- By FY01, develop a knowledge management system to reduce information obtained and predict performance and health risks.

Major Technical Challenges

Developing strategies and products to protect, sustain and enhance soldier performance requires the development and application of scientific data and knowledge. Strategies and products must remain effective in various com-

binations and in realistic operational tests. One example is sleep management. Strategies that combine the use of pharmaceutical agents, naturally occurring hormones (such as melatonin), timing of bright lights, and feeding schedules are needed. Various combinations of these factors must be explored to develop the best wake/rest management strategies for realistic operational scenarios.

Specific technical challenges are:

- Understanding sleep physiology and the purpose of restorative sleep.
- Modeling physiological measures to provide commanders with health and performance (readiness status).
- Defining the operational zones of caution: operational environments in which a soldier is currently at a minimal risk, but may become a casualty with continued exposure to the environment.
- Developing sensors and biomarkers to provide information about soldiers' status and the operational environment.
- Integrating physiological models and instrumentation into a set of tools that will provide rapid and meaningful information about soldiers' operational readiness to commanders.

d. Combat Casualty Care

Goals and Timeframes

The goal of this program is to save lives far forward. This goal will be achieved by improving the delivery of far-forward resuscitative care, minimizing lost duty time from minor battle and non-battle injuries, reducing unnecessary evacuations, and decreasing the resupply requirements of all forward echelons of care. Near-term objectives include general improvements in currently approved treatments, techniques, solutions, etc. Specifically:

- By FY98, develop the miniSTAT, an evacuation and en route care device that allows far-forward monitoring to assist in diagnosis and treatment.
- By FY00, introduce a microencapsulated antibiotic to allow site-specific administration of antibiotics.
- By FY99, produce a forward, mobile, digitally instrumented surgical hospital by introducing the advanced surgical suite for trauma casualties (ASSTC).
- By FY99–00, develop treatment/triage algorithms to aid the medic in treatment.

Mid-term goals include introduction of improved blood preservatives (FY00–03), small volume resuscitation fluids (FY00–03), local hemostatic agents (FY01), a transport for en route care (FY02), and a rapid fluid warmer and infusion device (FY02). Far-term goals include noninvasive physiological sensors (FY02–08), the use of nanotechnology for smart devices and sensors (FY02–10), development of lightweight energy generators for medical use (FY02–10), and the use of hibernation induction triggers for metabolic down-regulation.

Major Technical Challenges

Developing effective interventions for far-forward casualty care requires both the application of new biological knowledge, and the adaptation of existing materials, signal-detection, and signal-processing technologies to new applications in biological systems and to the unique needs of the battlefield environment. In many cases, evaluation of candidate technologies depends on animal models to identify those candidates with the highest potential to successfully demonstrate both safety and efficacy. Ultimately, all medical products must be able to satisfy FDA requirements for safety and effectiveness.

Major technical challenges include:

- Developing lightweight battery energy generation, and computing capability necessary to support the demands of the computer-aided diagnostic sensor/computer interface system.
- Developing the biotechnology, nanotechnology, pharmacologic interven-

tions, and miniaturized equipment necessary to induce metabolic down-regulation far forward.

- Overcoming the problem of applying local hemostatic agents (e.g., fibrin glues) to the wet surfaces of a hemorrhaging wound.
- Identifying early prognostic physiological indicators of shock, and developing corresponding noninvasive or minimally invasive sensing technologies.
- Developing online/real-time human physiologic databases from prehospital trauma settings.
- Stabilizing red blood cells without destroying function while eliminating in-theater pretransfusion processing requirements.
- Improving knowledge regarding the physiologic and cellular factors underlying the body's response to hemorrhage and subsequent resuscitation.
- Reversing complex detrimental inflammatory and physiological cascades initiated by reduced blood flow and anoxia subsequent to hemorrhage.
- Learning more about the detailed mechanisms responsible for brain edema and cytotoxicity following head injury.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Medical and Biomedical Science and Technology is shown in Table IV–34.

5. Linkages to Future Operational Capabilities

The influence of this technology area on TRADOC FOCs is summarized in Table IV–35.

Table IV–34. Technical Objectives for Medical and Biomedical Science and Technology

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Infectious Diseases of Military Importance	Vaccine vectors Synthesized antiparasitic drugs Genetically engineered vaccines Malaria genome sequencing	Peptide synthesis Countermeasures to parasitic drug resistance Proteosome delivery Single step field assays Advanced adjuvants	Combined oral vaccines Topical antiparasitic drugs Single dose vaccines
Medical Chemical and Biological Defense	Confirmation diagnostics Cyanide exposure field diagnostic test kit Cyanide pretreatment Nerve agent exposure field diagnostic test kit Topical skin protectant	Advanced anticonvulsant Bioengineered toxin scavengers Catalytic pretreatment for a nerve agent Multichambered autoinjector Reactive topical skin protectant	Catalytic scavenger for broad range of CW agents Combined oral vaccine Immunoprophylaxis for CW agents Medical countermeasures against vesicants Nucleic acid immunization Receptor targeted therapeutic agents
Army Operational Medicine	Laser effects model Pharmacological strategies to enhance restorative sleep Training strategies to enhance upper body strength and endurance Heat stress model to predict soldier performance decrements	Blunt trauma models laser injury treatments Laser injury treatments Enhanced crew rest guidance Training strategies to optimize specific physiological capabilities Strategies to reduce heat stress Performance-enhancing ration components	Physiological status models Sleep/alertness enhancers Treatments for laser retinal injury Memory enhancers Nonsteroidal strength enhancers

Table IV–34. Technical Objectives for Medical and Biomedical Science and Technology (continued)

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Combat Casualty Care	Microencapsulated antibiotic Far-forward monitoring/Ministat Surgical suite for trauma casualties/ASSTC Treatment/triage assist algorithm	Improved blood preservative Small volume resuscitation fluid Rapid fluid warmer and infusion device En route care transport Local hemostatic agents	Hibernation drug/metabolic down regulation Noninvasive physiological sensors Use of nanotechnology for smart systems Lightweight energy generators

Table IV–35. Medical and Biomedical Science and Technology Linkages to Future Operational Capabilities

Technology Subarea	Integrated and Branch/Functional Unique Future Operational Capabilities
Infectious Diseases of Military Import	TR 97–026 Deployability TR 97–029 Sustainment TR 97–031 Sustainment Services TR 97–044 Survivability—Personnel MD 97–007 Preventive Medicine MD 97–010 Medical Laboratory Support
Medical Chemical and Biological Defense	TR 97–029 Sustainment TR 97–038 Casualty Care, Patient Treatment, and Area Support TR 97–044 Survivability—Personnel MD 97–004 Combat Health Support in a Nuclear, Biological, and Chemical Environment MD 97–007 Preventive Medicine MD 97–010 Medical Laboratory Support
Army Operational Medicine	TR 97–002 Situational Awareness TR 97–007 Battlefield Information Passage TR 97–018 Relevant Information and Intelligence TR 97–023 Mobility—Combat Dismounted TR 97–029 Sustainment TR 97–038 Casualty Care, Patient Treatment, and Area Support TR 97–044 Survivability—Personnel TR 97–048 Performance Support Systems TR 97–053 Embedded Training and Soldier–Machine Interface MD 97–007 Preventive Medicine MD 97–009 Combat Stress Control MD 97–010 Medical Laboratory Support
Combat Casualty Care	TR 97–002 Situational Awareness TR 97–007 Battlefield Information Passage TR 97–024 Combat Support/Combat Service Support Mobility TR 97–026 Deployability TR 97–029 Sustainment TR 97–031 Sustainment Services TR 97–035 Power Sources and Accessories TR 97–036 Nonprimary Power Sources Combat Vehicles/Support Systems TR 97–038 Casualty Care, Patient Treatment, and Area Support TR 97–044 Survivability—Personnel TR 97–048 Performance Support Systems MD 97–001 Patient Evacuation MD 97–005 Far-Forward Surgical Support MD 97–006 Hospitalization MD 97–008 Combat Health Logistics Systems and Blood Management MD 97–010 Medical Laboratory Support

R. SENSORS

1. Scope

By providing critically required military capabilities detailing troop positions, target locations, and battlefield conditions, sensors and information processing technologies form an enabling array of systems on Army platforms. Flexible robust sensor systems have significantly increased Army warfighting capabilities and become a true force multiplier. Sensor technologies depend upon research provided by the Army Research Office (ARO), the RDECs, ARL, and federated partners. This area develops technologies in five subareas: radar sensors; EO sensors; acoustic, magnetic, and seismic sensors; ATR; and integrated platform electronics.

2. Rationale

Sensor technology provides the "eyes and ears" for nearly all Army tactical and strategic weapon systems as well as the intelligence community. Sensors support effective battlefield decision making and contribute to achieving the Joint Chiefs of Staff (JCS) top five future joint warfighting capabilities. Sensors represent a major cost factor for weapon systems, which is addressed in this program. Costs include affordable integrated circuits, ultra-large and multicolor IRFPAs, multifunction multiwavelength lasers, common modules, shared apertures, computer M&S, and adaptive processing. Expected payoffs include 50 percent reduction in cost of imaging radars and IR search track sensors, and 10 to 1 improvement in thermal sensitivity of IR sensors. Sensors are integral and fundamental to achieve situational awareness on the battlefield to win the information war. Because of their pervasiveness, sensors have multiple transitional opportunities, including for the 21st century soldier. Sensors are vital to the survivability of soldiers and the weapon platforms on the battlefield.

3. Technology Subareas

a. Radar Sensors

Goals and Timeframes

Radar is the sensor for all-weather detection of air, ground, and subsurface targets. This subarea includes technology developments involving enhanced and new capabilities associated with wide area surveillance radars, tactical reconnaissance radars, and airborne and ground fire control radars. Objectives include understanding the phenomenology and applications of ultrawideband (UWB) SAR to enable detection and classification of stationary targets that are subsurface or concealed by foliage or camouflage. This technology would enable development of a foliage penetration (FOPEN) radar capable of real-time image formation in operational scenarios. The system could be expanded to support a ground penetration (GPEN) radar capable of collecting subsurface target data.

A primary goal is the R&D of affordable battlefield fire control radar (FCR) technology to improve detection, tracking, and discrimination of high value stationary and moving targets for the Longbow Apache and Comanche programs as well as vehicle-based systems such as the moving target indicator ground radar (MGR) in the Target Acquisition ATD and the rapid target acquisition system for crew-served tube-launched, optically tracked, and wire command-linked (TOW).

Augmenting the programs listed above are fundamental studies of the phenomenology associated with target acquisition, including target and clutter characteristics, resolution enhancement techniques, and algorithmic studies, such as the real aperture stationary target radar (RASTR) program. These are designed to investigate performance enhancements through evaluation of improvements in a software environment based on high resolution data sets. Milestones are as follows:

- Begin test of GPEN crane SAR (FY97).
- Collect data and analyze ATR algorithm performance (FY99).

- Complete Ka-band polarimetric monopulse radar to support MGR studies (FY98).
- Apply direct digital synthesizer (DDS) and wideband transceiver technology development to stationary target fire control radars (FY97–99).
- Improve stationary target algorithms to allow for autonomous adaptation to various clutter backgrounds and strive for a probability of detection greater than 80 percent, with false alarm rates much less than $0.1/km^2$.

Major Technical Challenges

Challenges include development of instrumentation for the understanding of wave propagation in background/clutter environments; development of high power, low frequency, wideband signals, and development of radar components and algorithms that support high probability of detection and classification of stationary and moving targets with low false alarm rates.

Specific challenges are:

- Real beam search OTM targeting for stationary ground targets.
- Buried target detection.
- Enhanced spatial resolution for operational radar.
- MMW E-scan antennas.
- Affordability by design.

b. Electro-Optic Sensors

Goals and Timeframes

The goals of tactical EO sensors are to provide passive/covert and active target acquisition (detection, classification, recognition, identification) of military targets of interest and to allow military operations under all battlefield conditions. Platforms using EO sensors include dismounted combat personnel, ground combat and support vehicles, tactical rotary-wing aircraft, manned/unmanned reconnaissance aircraft, and ballistic/theater missile defense. Major milestones are: near-infrared (NIR) LADAR for reconnaissance, surveillance, and target acquisition (RSTA) (FY97); thin-film, low-cost uncooled sensors and smart dual-color sensors (FY99); multidomain smart sensors with shared aperture (FY03); and integrated detector arrays that incorporate advanced diffractive optics post-processing circuitry (FY03).

Major Technical Challenges

Technical roadblocks to overcome include:

- Growth of thin film materials for uncooled detectors.
- On-chip readout circuits for analog-to-digital (A/D) conversion and neuromorphic circuits.
- Monolithic integration of detector, readout, and processing modules.
- Low light level solid-state sensors.
- Fusion algorithms for a multidomain sensor system.
- Sensor performance in naturally occurring and battlefield generated countermeasures.
- Multidomain signature databases.
- Design of diffractive optical elements (DOEs).
- Integration of DOEs, detectors, and post-processing circuitry in a single device.
- Effective, affordable laser hardening for multifunction, multiband laser sources for active sensors.
- Multifunction, multiwavelength laser sensors.

c. Acoustic, Magnetic, and Seismic Sensors

Goals and Timeframes

This program seeks to provide real-time tracking and target identification for a variety of battlefield ground and air targets. Desired sys-

tems include unattended surveillance sensors and target engagement sensors. Advances in signal processing devices and techniques have made acoustic sensors realizable and highly affordable. Both continuous signals, such as engine noise, and impulsive signals, such as gun shots, are of interest. Enhancing hearing for individual soldiers is also important, and efforts are under way to extend the audible range and frequency response of an individual soldier. Goals include enhanced tracking and identification algorithms, creation of a robust target signature database and algorithm development laboratory (FY97), and detection and tracking of large formations of battlefield targets (FY98).

Major Technical Challenges

Technical risks derive largely from the immature nature of battlefield acoustics technology. Advances in digital signal processing will allow new algorithms to be implemented in affordable packages. Specific technical challenges include:

- Advanced target identification algorithms.
- Multitarget resolution.
- Detection and identification of impulsive acoustic signatures.
- Platform and wind noise reduction techniques.
- Compact array design for long range hearing.

d. Automatic Target Recognition

Goals and Timeframes

ATR systems will provide sensors with the capability to recognize and identify targets under real-world battlefield conditions. ATR technologies and systems will increase the capabilities of sensors far beyond today's capabilities. They will provide the future Army with target recognition and identification capabilities that will maintain and increase dominance over all adversaries.

Just as sensor systems are the "eyes" for tactical and strategic weapon systems, ATR systems will be the "brains" for these weapon systems. ATR systems and technologies will allow weapon systems to automatically identify targets, thereby (1) increasing lethality and survivability, (2) reducing the cost of employing advanced high priced weapons, and (3) eliminating or at least reducing the cost and tragedy of losses from friendly fire. In addition, ATR will aid the image analyst to screen the ever-expanding imagery derived from high resolution, wide-field-of-view SAR systems.

In the near term (FY97–98), the Army's goals in ATR are to do ten target classes, with identification rates nearing 75 to 80 percent and significantly reduced false alarm rates. In the mid term (FY99–03), ATR systems are to handle 20 target classes with improved detection and false alarm rates. In the far term (FY04–12), ATR systems will use rapid training on minimal data to additionally improve performance.

Major Technical Challenges

Technology integral to ATR include processors, algorithms, and ATR development tools, which include M&S. Today, the focus is on single sensor and multiple sensor ATR algorithm development. While processor development is being successfully leveraged off the highly competitive commercial market and the importance of development tools remains high, single and multiple sensor algorithm development programs are the key to successful development of ATR systems for the Army. Ongoing data-driven and model-based algorithm development programs are providing results that include detection rates approaching 100 percent, identification rates in the 80 percent range, and significant reductions in false alarms. In the mid- and far-term, these developments will translate into fielded ATR systems that will significantly increase soldiers' capabilities and reduce their workload.

e. Integrated Platform Electronics

Goals and Timeframes

Integrated platform electronics (IPE) focus on the integration technologies, disciplines, stan-

dards, tools, and components to physically and functionally integrate and fully exploit electronic systems for airborne (helicopters, remotely piloted vehicle (RPV), and fixed wing), ground, and human platforms. Integrated electronics approaches typically result in systems at half the cost and weight of conventional approaches, while providing virtually 100 percent of platform mission capability. One milestone will be to demonstrate an optical backplane system that will provide a 40 percent increase in bandwidth (FY98).

Major Technical Challenges

Determine an architecture or set of architectures so robust that they can readily accept technology innovations developed in the commercial sector. Improve reliability to reduce logistics, deployability, and support costs. Develop standardized image compression techniques and architectures to permit transfer of images with sufficient clarity and update rates to support digitization of the battlefield.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Sensors is shown in Table IV–36.

5. Linkages to Future Operational Capabilities

The influence of this technology area on TRADOC FOCs is summarized in Table IV–37.

Table IV–36. Technical Objectives for Sensors

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Radar Sensor	COTS processor for target acquisition Complete Ka-band database of targets and clutter Develop Ka-band polarimetric monopulse radar testbed	Demonstrate radar for tactical unmanned aerial vehicle (TUAV) Stationary target indicator (STI) algorithm insertion in MGR for Target Acquisition ATD Demonstrate unmanned wheeled vehicle (UWV) FOPEN SAR—all weather, wide area detection of targets in foliage Reduce antenna size requirement by 50%	Demonstrate fully integrated wideband digital receiver for battlefield radar Demonstrate UWB GPEN capabilities against distributed targets Implement coherent G-band radar for fire control
Electro-Optics Sensors	High resolution image intensifier system Dual-color sensor demonstration Quantum well array sensor Advanced material for uncooled sensor	NIR LADAR sensor for RSTA Advanced integrated man-portable system (AIMS) lightweight sensor and display modules for multiple infantry missions Thin-film, low-cost uncooled sensor Dual-color smart sensor	Multidomain smart sensor system with shared aperture
Acoustic, Magnetic, and Seismic Sensors	Develop improved target identification algorithms Develop improved beamforming algorithms Evaluate acoustic medical sensors Develop acoustic algorithm Develop evaluation laboratory	Develop long-range artillery and rocket location technology Investigate widely dispersed sensor concepts Develop enhanced hearing technology for soldier	Develop wind and vehicle noise reduction techniques Integrate weather models into acoustics sensors Develop advanced acoustic imaging techniques

Table IV–36. Technical Objectives for Sensors (continued)

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Automatic Target Recognition Sensors	Multisensor ATRs providing 80% open target recognition 6X search rate Ten target classes	Multisensor ATRs providing 90% recognition of ground targets in mod-high clutter with acceptable false alarms 60X search rate 20 target classes	Multisensor ATRs providing 95–97% recognition with acceptable false alarms 1000X search rate ATR with rapid training on minimal data
Integrated Platform Electronics	Reduce tank crew manning 50% Demonstrate super-high-density connector on a standard electronic module—format E (SEM–E)	Improve navigation technology by one order of magnitude in all environments Demonstrate tank crew 50% reduction using crewman's associate integration	Demonstrate immersion cooled SEM–E > 1000 watts Demonstrate 20 GHz network for combined digital, video, and RF

Table IV–37. Sensors Linkages to Future Operational Capabilities

Technology Subarea	Integrated and Branch/Functional Unique Future Operational Capabilities
Radar Sensors	TR 97–006 Combat Identification TR 97–017 Information Display TR 97–020 Information Collection, Dissemination, and Analysis TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–022 Mobility—Combat Mounted TR 97–027 Navigation TR 97–040 Firepower Lethality TR 97–041 Operations in an Unexploded Ordnance/Mine Threat Environment TR 97–043 Survivability—Materiel
Electro-Optic Sensors	TR 97–006 Combat Identification TR 97–017 Information Display TR 97–020 Information Collection, Dissemination, and Analysis TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–022 Mobility—Combat Mounted TR 97–024 Combat Support/Combat Service Support Mobility TR 97–027 Navigation TR 97–028 Unmanned Terrain Domination TR 97–040 Firepower Lethality TR 97–043 Survivability—Materiel
Acoustic, Magnetic, and Seismic Sensors	TR 97–006 Combat Identification TR 97–017 Information Display TR 97–020 Information Collection, Dissemination, and Analysis TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–022 Mobility—Combat Mounted TR 97–027 Navigation TR 97–028 Unmanned Terrain Domination TR 97–040 Firepower Lethality TR 97–043 Survivability—Materiel

Table IV–37. Sensors Linkages to Future Operational Capabilities (continued)

Technology Subarea	Integrated and Branch/Functional Unique Future Operational Capabilities
Automatic Target Recognition Sensors	TR 97–006 Combat Identification TR 97–017 Information Display TR 97–020 Information Collection, Dissemination, and Analysis TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–022 Mobility—Combat Mounted TR 97–027 Navigation TR 97–028 Unmanned Terrain Domination TR 97–040 Firepower Lethality TR 97–043 Survivability—Materiel
Integrated Platform Electronics	TR 97–003 Mission Planning and Rehearsal TR 97–017 Information Display TR 97–024 Combat Support/Combat Service Support Mobility TR 97–043 Survivability—Materiel TR 97–052 Training Aids, Devices, Simulators, and Simulations Fidelity Requirements

S. GROUND VEHICLES

1. Scope

The Army focuses its ground vehicle technologies on those that provide our soldiers with the capabilities needed to dominate the maneuver and win the information war. The ground vehicles technology area incorporates efforts to support the basic Army and Marine Corps land combat functions: shoot, move, communicate, survive, and sustain. This technology area comprises the following subareas: systems integration, vehicle chassis and turret, integrated survivability, mobility, and intravehicular electronics suite. These subareas are illustrated in Figure IV–19.

2. Rationale

One of the mounted forces' most critical deficiencies in the post-cold-war era is the inability to rapidly deploy forces for worldwide contingency missions. Current mounted forces are capable but take too long to be deployed, have a large logistics tail, and are ill-suited to the third world infrastructure. Current combat vehicles rely on traditional materials for construction, communications, training, passive armor protection against munitions, and conventional mobility.

A lighter "heavy" force is required that can deploy overseas in less time, with fewer ships, and reduced CSS requirements and yet be equally lethal, survivable, and cost effective. Materiel, smart weapon, and survivability advances can lead to a fully air deployable armored assault force or a more deployable heavy assault force requiring 50 percent or less of current logistics assets. Advanced ground vehicle technologies will enable selected future systems to be air deployable; this is not possible with current systems.

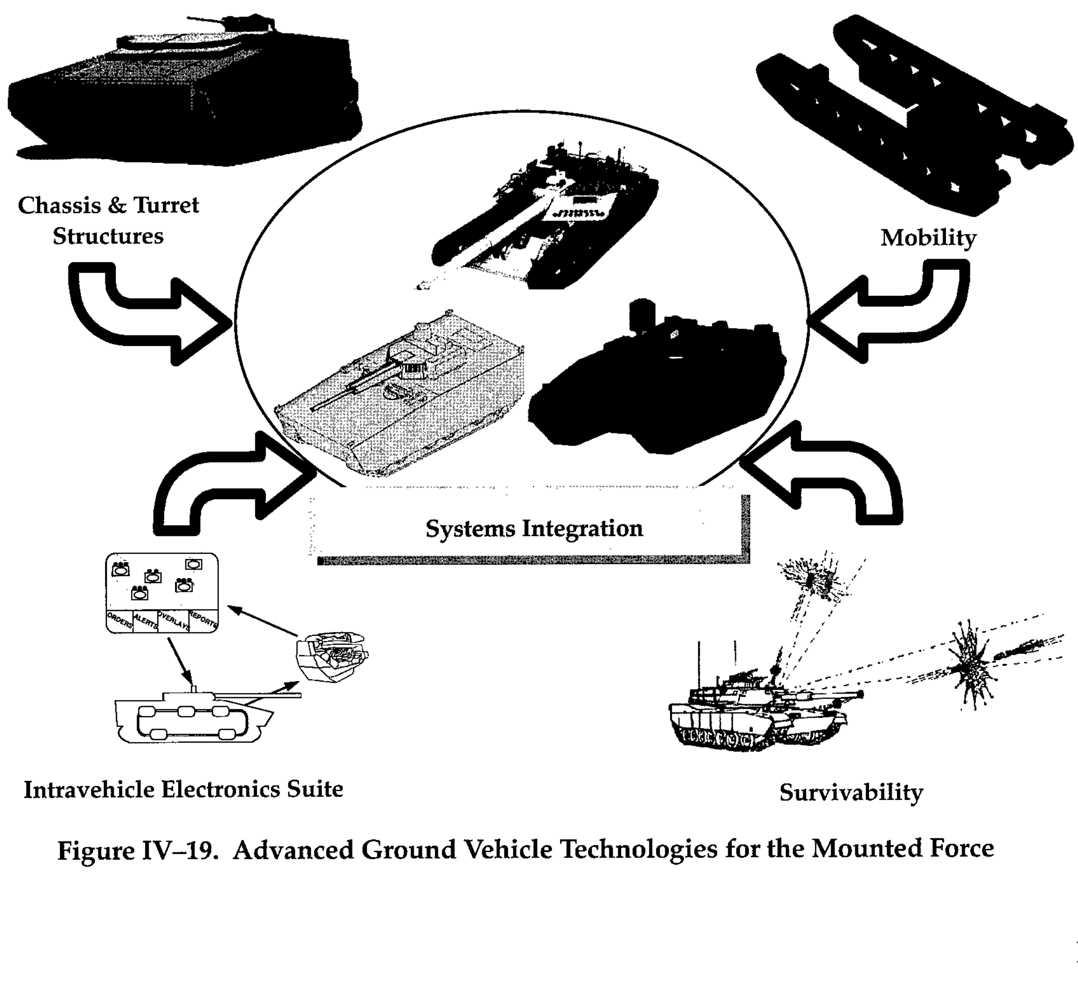


Figure IV–19. Advanced Ground Vehicle Technologies for the Mounted Force

Ground vehicle platforms require targeting, location, and acquisition systems capable of rapid detection, recognition, identification, handoff, or engagement of both ground and aerial targets beyond the threat's detection range. Systems must perform effectively day or night in adverse weather, in cluttered background environments, and in the presence of countermeasures that include jamming, screening, and the use of low observable and active defense systems. Ground vehicle platforms must possess the capability to execute at an improved maneuver tempo as a result of digitizing the battlefield.

Through the integrated concept team (ICT) process, the user now has greater influence over S&T planning. The ICTs at the U.S. Army Armor Center, Fort Knox, and the U.S. Army Infantry Center, Fort Benning, have refocused near-term S&T towards the future scout and cavalry system (FSCS) and Abrams tank modernization. Far-term S&T will be focused toward the next generation "tank" and infantry vehicle. Detailed ICT ground vehicle activities are described in Section III–G.

3. Technology Subareas

a. Systems Integration

Goals and Timeframes

Systems integration/virtual prototyping of future vehicles uses M&S and system-level advanced technology demonstrators to (1) develop preliminary concepts, (2) optimize design, (3) maximize ground vehicle force effectiveness, and (4) drive technology goals. STOs IV.S.05, Virtual Prototyping Integrated Infrastructure, and IV.S.09, Combat Vehicle Concepts and Analysis, support ground vehicle virtual prototyping. Future vehicle concepts and designs are the realization of the Army and Marine Corps users' requirements and the opportunities harvested from the results of previous technology subsystem development programs.

The goal is to demonstrate the feasibility and potential of lighter, more lethal, and survivable ground combat vehicles. Four types of modeling and simulation will be employed: engineering models, constructive simulation, distributed simulation, and virtual-reality prototyping. The analyses conducted will span the entire vehicle combat spectrum and will be performed physically, analytically, and interactively using simulation methodologies. Virtual concepts and designs will mirror technology and can be readily evaluated for mobility, agility, survivability, lethality, and transportability, forming the basis for validation, verification, and accreditation. Tradeoff studies performed under STO IV.S.09 will be used to determine optimal technology mix. Working closely with the user, we will change those virtual systems to real-world 6.3 ATDs that will yield maximum payoff. System-level ATDs planned in the FY98–13 time frame include:

- Future scout and cavalry system (FSCS).
- Future infantry vehicle (FIV).
- Future combat system (FCS).

By 1999, demonstrate a virtual prototyping infrastructure that will reduce system-level development time and cost by 50 percent. By 2000, complete validation of the virtual prototyping process.

Major Technical Challenges

The major challenge is to provide the user with systems that can attain an effective balance between increased fighting capability, enhanced survivability, and improved deployability, while meeting or exceeding operational effectiveness, cost, manufacturing, and reliability/maintainability goals.

b. Chassis and Turret Structures

Goals and Timeframes

Through the use of composite, titanium-based, and other lightweight materials, technologies are being developed that will make future combat vehicles more lightweight and deployable (33 percent lighter in the structure and armor combined), versatile (multiple combat and support roles), and survivable (better ballistic protec-

tion and reduced signature). These technologies will be developed for combat vehicles to optimize and exploit the structural integrity, durability, ballistic resistance, repairability, and signature characteristics of a vehicle chassis and turret fabricated primarily from composite or titanium-based materials. Current vehicle chassis efforts center on the development of vehicles composed of advanced lightweight materials to demonstrate the feasibility of this approach. STO III.G.1 supports development of a 22-ton composite armored vehicle.

By 1998, demonstrate a 22-ton tracked vehicle with 33 percent reduced structural/armor weight. By 1999, simulation tools for composite material design and fabrication will be developed and validated. By 2004, demonstrate minimum weight structural designs with structural efficiencies exceeding 80 percent for a 40-ton combat vehicle (FCS).

Major Technical Challenges

Use of composite materials or titanium as the primary structure in the combat vehicle chassis is new. Composite issues include durability, producibility, and repairability. Titanium has yet to be used on combat vehicles because of cost. Through an IPPD approach, all issues relating to the successful fielding of a combat vehicle, including cost, are addressed.

c. Integrated Survivability

Goals and Timeframes

This technology effort's objectives are to provide an integrated survivability solution that will protect ground combat vehicles from a proliferation of advanced threats. With ever-changing threats and missions, the integrated survivability approach allows for flexibility in meeting mission needs. Detection avoidance, hit avoidance, and kill avoidance technologies will be developed and integrated to enhance overall vehicle survivability.

Detection avoidance technologies include signature management and visual perception. Signature management efforts are focused on exploring vehicle signatures in the visual, thermal, radar, acoustic, and seismic areas and in various atmospheric conditions. Visual signature analysis will be enhanced through the use of visual models and laboratory experimentation of visual perception.

Hit avoidance technologies protect ground vehicles through the use of sensors and countermeasures. The sensors detect incoming threats and the countermeasures confuse or physically disrupt incoming threats. The Army is developing electronic countermeasure and sensing technologies to defeat current and future smart munitions. By 2002, identify best countermeasure technology against all antiarmor threats. By 2005, demonstrate active protection against tube-launched kinetic energy (KE) and chemical energy (CE), large top attack, threats.

Kill avoidance technologies include the development of armor, laser protection work, and the exploration of non-ozone depleting substances to use for fire suppression. Armor plays a synergistic role with detection and hit avoidance on the modern battlefield. It provides the last line of defense. By 2000, demonstrate armors for medium caliber KE threats with 50 percent improved space efficiency over the 1999 state of the art while remaining compatible with the FCS structure. By 2003, demonstrate FCS armors with 25 percent frontal, 15 percent flank, and 30 percent top protection improvements over 1999 state-of-the-art technologies. Laser protection technologies are being developed to prevent blinding and eye damage of vehicle crews due to the use of lasers on the battlefield. Laser protection for all unity vision devices (STO IV.S.07) will provide eye safety against enemy agile wavelength laser threats. The work in this area is twofold. First, nonlinear optical materials developed commercially and at other DoD agencies will be characterized. Second, work to design and integrate a retrofittable optical surveillance system is being performed. Finally, in the area of advanced

protection technologies, is the exploration of non-ozone depleting substances for fire suppression use. Work in this area will focus on demonstrating environmentally and toxicological acceptable replacements for Halon 1301 in fire suppression systems in crew occupied compartments of ground combat vehicles.

None of the aforementioned technologies alone can ensure survivability and mission flexibility. The integrated survivability approach ensures the proper mix of these technologies so that survivability and mission flexibility may be achieved.

Major Technical Challenges

Cost of the currently identified technologies are prohibitive for application to all vehicles. Many of these technologies have significant weight, volume, electrical power, and thermal loading requirements. Insertion of these technologies into fielded systems can be costly and time consuming.

d. Mobility

Goals and Timeframes

The mobility technology effort focuses on the "move" function of tracked and wheeled land combat vehicles. Mobility components for ground vehicles include the suspension, track, wheels, engine, and transmission (conventional and electric drive).

While contributing to both the survivability and lethality of combat vehicles, mobility technology plans call for doubling the cross-country speed of combat vehicles. Military vehicle cross-country speed is usually limited by the driver's ability to tolerate the vibration energy transmitted through the suspension. Electronic controls have made it possible to actively control both the spring and damping rates of "active" suspension systems, reducing structural vibration and shock. By 2001, semiactive suspension and band track technologies applicable to the tracked fleet will be demonstrated. By 2005, a 40 percent increase of cross country speed of a 40–50-ton combat vehicle will be demonstrated.

Hybrid electric technologies are being pursued as means to enhance mobility. Substantial reduction in fuel consumption can potentially be achieved through advanced engine control, stored energy capabilities, and energy regeneration. In coordination with other government agencies, including DARPA, Navy, and the Army, several electric drive technology developments are being leveraged for Army combat vehicle application. In particular the DARPA/Army joint program combat hybrid power system will demonstrate in a system integration laboratory an integrated combat power system in the year 2000.

While most vehicles, except the tank and its derivatives, use commercial diesel engines, they operate at or above their commercial power ratings. Even though their power density is relatively high, an engine that is sufficiently compact for an FCS is not commercially available and must be developed. Early activities will focus on determining the concepts and advancing the technologies required to allow the advanced engine to be developed. It is projected that by 2013 a complete propulsion system will be developed that has a power density of 8-sprocket horsepower per cubic foot (versus 3.3 for the M1 Abrams).

Major Technical Challenges

For a 40–50-ton electric drive combat vehicle, major challenges include the need to operate the power electronics at elevated temperatures without overheating. A high power density low-heat rejection engine will also be a challenge.

For advanced track systems, the major challenge is to develop light weight track while maintaining track durability. Rubber band track must be developed to move beyond lightweight applications into the medium-to-heavyweight vehicles.

e. Intravehicular Electronics Suite

Goals and Timeframes

The goal of this subarea is to develop a standardized framework within which to seamlessly integrate vehicle electronic subsystems with advanced soldier–machine interfaces. This will enable current and future ground vehicles with a reduced crew to maintain superior combat effectiveness on the digital battlefield, while reducing crew workload. By 2000, demonstrate 25 percent crew efficiency improvement for a three-man crew. By 2008, demonstrate 50 percent crew efficiency improvement for a two-man crew.

The intravehicular electronics suite will provide the necessary integration flexibility to support the wide-ranging battlefield digitization functionality over the next decade. It is the first step toward creating a general purpose electronic platform for multipurpose sensors and sensor fusion.

The flexibility inherent in this system allows for cost-effective improvements in performance and capability. This improvement can be incremental or continuous, adding or upgrading the processors, memory, or software functionality necessary to keep pace with the demands of the battlefield. Reliance on commercial, open standards for this electronics suite, coupled with the ability to continuously improve the system, will delay obsolescence of the system. The Army will be able to use state-of-the-art hardware at any time from multiple sources with minimal risk or development. By 2000, demonstrate a 30 percent reduction in cost per line of source code. By 2002, demonstrate a ten-fold improvement in electronics system performance.

Major Technical Challenges

Specific technical challenges include:

- Maintaining situational awareness while operating from the hull and relying on indirect vision systems.
- Development and demonstration of mission rehearsal (embedded training) technologies.
- Demonstration of advanced processor/ network commercial technologies that are suitable for military use.
- Real-time battlefield information distribution within a vehicle.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Ground Vehicles is shown in Table IV–38.

5. Linkages to Future Operational Capabilities

The influence of this technology area on TRADOC FOCs is summarized in Table IV–39.

Table IV–38. Technical Objectives for Ground Vehicles

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Systems Integration	Develop and analyze FIV and FSCS concepts Downselect FSCS lethality option with probability of kill (P_{kill}) = 1 at 50% increased engagement range	Demonstrate in the field a scout vehicle with 10% survivability increase, 500% increase in target detection rate, and 10% mobility increase Demonstrate FIV and FSCS concepts in a virtual environment	Demonstrate in the field an FCS (Abrams replacement) with 40% increase in cross-country speed, 20% increase in fuel economy, and 33% reduced gross vehicle weight (GVW) Demonstrate FIV (Bradley replacement) with 50% increase in survivability, 100% increase in mobility, and 60% increase in troop capacity
Vehicle Chassis and Turret	Complete 6,000-mile Composite Armor Vehicle ATD endurance experiment	Develop and demonstrate a vehicle chassis and turret to meet future combat system 40-ton GVW requirement	Develop vehicle chassis and turret to support AAN advanced systems
Integrated Survivability	Demonstrate improved Abrams frontal armor with 35% weight reduction	Demonstrate side ballistic panels with 75% reduction in detectability Demonstrate armor to defeat medium caliber KE threats with a 50% space efficiency improvement Demonstrate armor with a 30% weight efficiency improvement Demonstrate active protection system to defeat KE and high explosive antitank threats with probability 0.8	Demonstrate FCS armor with 25% frontal penetration reduction, 25% flank penetration reduction, and 35% top penetration reduction Apply integrated armor/active protection system to FIV
Mobility	Demonstrate semiactive suspension on Bradley fighting vehicle that will yield a 30% mobility improvement Determine active suspension requirement for heavy tracked vehicles	Demonstrate M2 Bradley track that will reduce vehicle signature by 30–50% with a 23% track weight reduction Demonstrate heavy vehicle band track with a 300% track pad life improvement Demonstrate high temperature silicon carbide switches to support electric drive	Demonstrate fully active electromechanical suspension on a >40-ton tracked vehicle Develop and demonstrate FCS power pack
Intravehicular Electronics Suite	Develop and demonstrate FSCS conceptual crew station simulator Demonstrate off-road driving using indirect vision at 50% direct vision rate	Demonstrate 50% improvement in three-man crew efficiency Demonstrate 25% cost reduction in vehicle electronics upgrades Demonstrate off-road driving using indirect vision at 100% direct vision rate	Demonstrate on a vehicle, a high power electronics suite Demonstrate a 50% increase in two-man crew efficiency

Table IV–39. Ground Vehicles Linkages to Future Operational Capabilities

Technology Subarea	Integrated and Branch/Functional Unique Future Operational Capabilities
Systems Integration	TR 97–002 Situational Awareness TR 97–004 Tactical Operation Center Command Post TR 97–012 Information Systems TR 97–017 Information Display TR 97–020 Information Collection, Dissemination, and Analysis TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–022 Mobility—Combat Mounted TR 97–023 Mobility—Combat Dismounted TR 97–034 Enemy Prisoner of War/Civilian Internee Operations TR 97–037 Combat Vehicle Propulsion TR 97–040 Firepower Lethality TR 97–042 Firepower Nonlethal TR 97–043 Survivability—Materiel TR 97–045 Camouflage, Concealment, and Deception TR 97–049 Battle Staff Training and Support TR 97–054 Virtual Reality TR 97–055 Live, Virtual, and Constructive Simulation Technologies TR 97–056 Synthetic Environment TR 97–057 Modeling and Simulation
Vehicle Chassis and Turret	TR 97–004 Tactical Operation Center Command Post TR 97–022 Mobility—Combat Mounted TR 97–026 Deployability TR 97–032 Sustainment Logistics Support TR 97–033 Sustainment Transportation TR 97–043 Survivability—Materiel TR 97–044 Survivability—Personnel TR 97–045 Camouflage, Concealment, and Deception
Integrated Survivability	TR 97–002 Situational Awareness TR 97–043 Survivability—Materiel TR 97–044 Survivability—Personnel TR 97–045 Camouflage, Concealment, and Deception
Mobility	TR 97–022 Mobility—Combat Mounted TR 97–026 Deployability TR 97–035 Power Source and Accessories TR 97–037 Combat Vehicle Propulsion TR 97–040 Firepower Lethality TR 97–043 Survivability—Materiel TR 97–044 Survivability—Personnel
Intravehicular Electronics Suite	TR 97–007 Battlefield Information Passage TR 97–011 Information Services TR 97–012 Information Systems TR 97–013 Network Management TR 97–014 Hands-Free Equipment Operation TR 97–016 Information Analysis TR 97–017 Information Display TR 97–018 Relevant Information and Intelligence TR 97–019 Command and Control Warfare TR 97–020 Information Collection, Dissemination, and Analysis TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–036 Nonprimary Power Sources Combat Vehicles/Support Systems TR 97–040 Firepower Lethality TR 97–053 Embedded Training and Soldier–Machine Interface TR 97–054 Virtual Reality TR 97–056 Synthetic Environment

T. MANUFACTURING SCIENCE AND TECHNOLOGY

1. Scope

The manufacturing science and technology (MS&T) area focuses on technologies that will enable the industrial base to produce reliable and affordable materiel for the soldier, with enhanced performance parameters, and in a reduced cycle time. The technologies in MS&T include processing and fabrication, manufacturing engineering, production management, design engineering, enterprise integration, IPPD, and flexible manufacturing systems capable of addressing both high and low volume dual-use production. The interrelationships among all these technologies are illustrated in Figure IV–20. MS&T addresses the needs of the soldier by deriving requirements from three thrusts: acquisition and sustainment driven needs, pervasive industrial base needs, and S&T needs and opportunities. Potential projects based on these needs are prioritized according to their relevance to TRADOC FOCs and their significance to the successful attainment of ATD and Advanced Concept Technology Demonstration (ACTD) objectives.

The MS&T program's three subareas are:

- *Advanced processing* of metals, composites, and electronics with emphasis on the development and validation of new manufacturing processes for defense-essential materials, components, and systems. Project technologies include validated process models, embedded sensors and adaptive control systems for composites and electronics manufacturing, improved composites airframe manufacturing for advanced helicopters, improved manufacturing and testing for advanced cooled and uncooled FLIR sensors, computer automated manufacturing for precision optics, manufacturing of advanced battery technology, flexible manufacturing for MMW transceivers, flexible manufacturing of missile seekers and assemblies, flexible manufacturing of munitions and munition components such as propellants, explosives, sensors, fuzing, and agile production control.

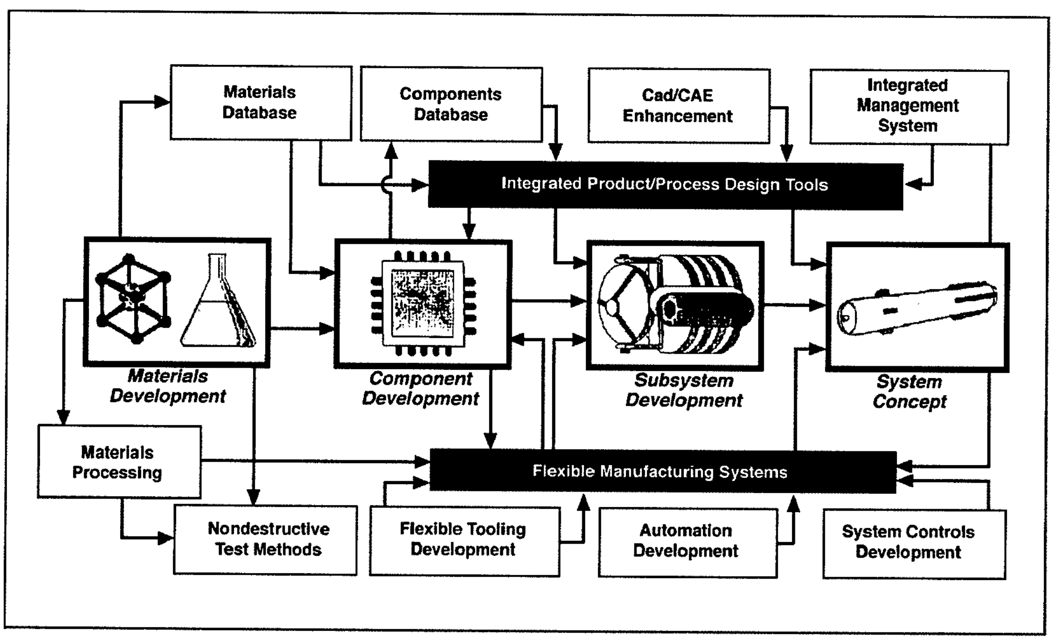


Figure IV–20. Relationships Among Integrated Product/Process Design Tools and Flexible Manufacturing Systems

- *Manufacturing engineering support tools* that encompass manufacturing technologies such as CAD, CAE, and computer-aided manufacturing (CAM); AI tools for a broad range of manufacturing processes; design and analysis tools for assessing product producibility and manufacturability; rapid prototyping; control and interface research for component modeling, and system integration and information infrastructure; industrial base modeling and production allocation for management of coordinated supply chain and surge production. This subarea focuses on developing tools for early involvement of the manufacturing discipline in the requirements and design process of new technologies.
- *Advanced manufacturing demonstrations* for the application of worldclass best manufacturing practices and procedures in a factory environment. These demonstrations are usually large scale, include the pertinent aspects of the enterprise, have specific goals, and are performed over a 2- to 4-year time period.

2. Rationale

Defense acquisition strategies reflect a significant reduction in weapon system development and production programs. The emphasis within DoD and the Army continues to be on upgrading and modifying existing systems while continuing to support the underlying doctrine of developing technologically superior weapon systems. This environment requires new processing and fabrication technologies and new manufacturing attributes (flexible, lean, agile) in order to economically produce a wide variety of products in lower volumes. Army MS&T must develop and adapt the technologies required to make weapon systems affordable both during materiel production and over the system life cycle.

3. Technology Subareas

a. Advanced Processing

Goals and Timeframes

The advanced processing subarea focuses on processing S&T that will lead to the production of affordable components with consistent and reliable properties. Emphasis is on process maturation and the development of technologies that can be implemented to control manufacturing processes.

The Army is focusing on the following advanced processing technology efforts:

- Develop manufacturing processes for second-generation IRFPAs/dewar/cooler assemblies (FY98) that provide technology capability for the Air/Land Enhanced Reconnaissance and Targeting (ALERT) ATD, Target Acquisition ATD, Hunter Sensor Suite ATD, and Rotorcraft Pilot's Associate ATD.
- Develop automated testing (FY98) and manufacturing processes for uncooled IR technologies (FY00) that have the potential technology for insertion into the Objective Individual Combat Weapon ATD and Force XXI Land Warrior program.
- Develop optical manufacturing processes for spherical lenses (FY05) that support a variety of ATDs that use optical components.
- Demonstrate an adaptive process controller for the resin transfer molding process for airframe structures (FY99).
- Fabricate thick composite parts (FY99) and in-situ sensors (Smartweave) that will impact the Composite Armored Vehicle ATD (FY98).
- Develop improved manufacturing technology to sustain the remanufacturing and repair of DoD rotary wing aircraft (FY01).

Other pervasive efforts include:

- Demonstrate integrated workcells for missile and munition seeker assemblies with associated process control systems (FY99).
- High-deposition welding of low-cost titanium for tank turrets (FY99).
- Develop laser-based optical prototyping system for titanium parts (FY98).
- Develop a casting process for beryllium aluminum (FY00).
- Develop MEMSs (FY98).
- Develop processes associated with flexible continuous processing of propellants and explosives using a twin screw mixer/extruder (FY98).
- Demonstrate advanced processing of solid thermoplastic elastomer gun propellants using in-process rheology control (FY98).
- Develop improved machining, grinding, and inspection processes for precision gears (FY01).
- Develop processes to improve manufacturing of fiber-optic cables.
- Develop coating systems for engine components.
- Develop advanced nonmetallic rechargeable battery with current application on SINCGARS radio, chemical mask sight, AN–PRC–104, KY–57, SAWELMILES II, Land Warrior, and potential applications to over 50 different Army end items (FY98).

Major Technical Challenges

The major technical challenges for improving processing and manufacturing technologies include increasing performance while decreasing size, weight, and life-cycle cost.

Specific challenges include:

- Implement in-process controls and improved manufacturing techniques that will reduce dependence on highly skilled labor, increase yields, and increase throughput for tri-service, second-generation, standard advanced IRFPAs/dewars/coolers assemblies.
- Improve testing and manufacturing techniques to reduce costs and increase throughput associated with large FPAs.
- Develop an embedded sensor system to monitor the resin flow through a composite preform during the RTM process.
- Eliminate costly dies and molds for fabrication of prototype titanium components and reduce costs associated with precision machining of beryllium aluminum components and precision gears.
- Develop and implement reconfigurable workcells, multimissile tooling and test stations, material handling control, and process control techniques.
- Miniaturize electromechanical systems to reduce power requirements and weight of soldier portable systems.
- Control of the manufacturing process to facilitate real-time correction and reduce or eliminate post-process inspection.
- Reverse engineering of legacy electronic systems to provide form, fit, and function for older weapon systems with today's production technologies.
- Develop safe, cost-effective, high quality equipment and processes for manufacture of energetic materials—propellants/explosives/pyrotechnics.
- Develop flexible manufacturing capability for prismatic cell packaging and bi-cells from commercial spinoffs that will allow low cost manufacturing of a variety of nonmetallic rechargeable battery configurations.
- Develop coating techniques for turbine blades and shrouds to improve perfor-

mance and reduce life-cycle cost of turbine engines.

b. Manufacturing Engineering Support Tools

Goals and Timeframes

Manufacturing engineering support tools are essential to improve design, process analysis, prototyping, and inspection processes for manufacturing components and systems. Current Army efforts include developing production engineering tools that will assess product producibility and manufacturability based upon analysis of CAD drawings (FY99), integrating a rapid prototyping system with production engineering tools to reduce product development time (FY00), and developing advanced integrated manufacturing for missile seekers and munitions (far term).

Major Technical Challenges

Challenges for developing manufacturing engineering support tools include the development of design and analysis tools for assessing product producibility and manufacturability; developing rapid prototyping tools, and advancing manufacturing technologies such as CAD/CAM/CAE and inspection. Some specific challenges are:

- Software environments capable of automatically transferring CAD drawings to machine shops and controlling the required equipment to produce a desired part.
- Cost estimator tools that provide economic analysis of fabricating a part based upon the output of a design analysis tool.
- Optimization of design versus fabrication process to minimize cost and cycle time via the development of a virtual factory capable of modeling factory floor processes.
- Quality assessment and control through computer vision inspection.
- Order release mechanism for electronic assembly systems.

c. Advanced Manufacturing Demonstrations

Goals and Timeframes

The advanced manufacturing demonstrations incorporate best manufacturing practices and integrated product and process development to merge innovative concepts and manufacturing technology into a system-level approach to integrated manufacturing. Army MS&T is currently conducting an industrial base pilot demonstration using the Longbow Apache fire-control-mast-mounted assembly as the demonstration article (FY98). A demonstration is planned using a missile IPPD to develop processing technology and producibility strategies during the earliest stages of production development (FY99). This latter activity is supportive of the EFOGM ATD, and the PGMM, Rapid Force Projection Initiative (RFPI), and Precision/Rapid Counter–Multiple Rocket Launcher (MRL) ACTDs. A planned demonstration pilot for MMW missile seekers (FY99) will provide for affordable/flexible manufacturing and design of these missile components.

Major Technical Challenges

The results and observations of industrial pilots indicate that implementation of enhanced business practices combined with technology insertion can significantly reduce cost, increase product quality, and ultimately develop the capability to produce a product in a lot size of one. The major challenges associated with advanced industrial practices include identifying, adapting, and implementing best manufacturing practices; identifying and implementing the appropriate tools for IPPD, and incorporating the changes into an enterprise's culture.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Manufacturing Science and Technology is shown in Table IV–40.

Table IV–40. Technical Objectives for Manufacturing Science and Technology

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Advanced Processing	Reduce the cost of tri-service second-generation standard IRFPA/dewar/cooler assembly by 30% and implement in Army and DoD systems Reduce 20% manufacturing cost of precision gear by improving grinding, and deburring, inspection processes Increase manufacturing process yield 50% for fiber-optic cables and harnesses Reduce optical components cost >20% for spherical lenses Use resin transfer molding for advanced airframe structures Develop noncontact, nondestructive test method to permit 100% evaluation of detector elements in FPAs Develop processes for 60% reduction in machining for beryllium aluminum components Twin screw processing of energetic materials Process scales up of CBD enzymes and antibodies Reduce testing time 75% for flexible static blade balancing technique for helicopter main rotorblades Demonstrate bidirectional through-wafer optical interconnects for advanced missile processors	Center for Electronic Manufacturing for supporting current and future changes in defense and commercial industrial base Advanced nonmetallic rechargeable batteries Smart microdevice for application on ultra-compact antenna technology and system integration for rotorcraft and helicopters Safe, environmentally acceptable, agile manufacturing technologies for propellants, explosives, and pyrotechnics that provide the flexibility to meet future production needs Develop real-time controlled welding process to reduce weld time by 50% for complex engine components Develop manufacturing processes for uncooled thermal imaging processors and advanced FPAs Fabricate advanced optical components such as aspherical lenses at >20% cost reduction Eliminate manual tooling fabrication for optics production Reduce thick composites fabrication cost for armored vehicles by 30% and labor by 50% using integrated process development Develop real-time processing tool to provide flow modeling database for highly reinforced composite materials Reduce the cost of biological stimulants Enhance manufacturing processes for photonics Lower missile seeker manufacturing costs by >30% Develop optimal machining and heat treat distortion processes for high performance gear materials Increase blade life 5% by developing helicopter integrated manufacturing for applying abradable shroud and abrasive blade coating Reduce cost of compressor impellers by 50% through improved tooling/processing for high rate compressor manufacturing	Reduce 50% cost of aircraft transmission capability to produce them from thermoplastic materials Reduce the cost of propellants, explosives, and pyrotechnics by at least 25% Develop manufacturing processes for monolithic, multifunction, multispectral advanced FPA sensor systems, multispectral staring FPA sensor systems, and on-chip massive optical parallel processors Develop advanced tooling for cylindrical and toroidal lenses Demonstrate an image control/neural network system to facilitate automated inspection of electronic modules Establish COE for biotechnology

Table IV–40. Technical Objectives for Manufacturing Science and Technology (continued)

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Manufacturing Engineering Support Tools	Improve producibility of early designs using quick-turnaround cell software	Develop enterprise metadatabase that puts information in a global form available to local shells	Develop advanced integrated manufacturing technologies (to include desktop tools and virtual factories) using integrated product development for the missile and munitions sector
Advanced Manufacturing Demonstrations	Reduce costs with a 15% weight reduction using integrated composite manufacturing for advanced aircraft Demonstration pilot for MMW seekers for 40% reduction in concept to hardware cycle time	Affordable manufacturing of rotorcraft systems through the use of turboshaft engine and rotorcraft airframe pilots	Battlefield Manufacturing Center (BMC) demonstration is planned

5. Linkages to Future Operational Capabilities

The influence of this technology area on TRADOC FOCs is summarized in Table IV–41.

Table IV–41. Manufacturing Science and Technology Linkages to Future Operational Capabilities

Technology Subarea	Integrated and Branch/Functional Unique Future Operational Capabilities
Advanced Processing	TR 97–001 Command and Control TR 97–007 Battlefield Information Passage TR 97–010 Tactical Communications TR 97–012 Information Systems TR 97–020 Information Collection, Dissemination, and Analysis TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–022 Mobility—Combat Mounted TR 97–023 Mobility—Combat Dismounted TR 97–027 Navigation TR 97–029 Sustainment TR 97–037 Combat Vehicle Propulsion TR 97–040 Firepower Lethality TR 97–043 Survivability—Materiel TR 97–044 Survivability—Personnel TR 97–057 Modeling and Simulation
Manufacturing Engineering Support Tools	TR 97–016 Information Analysis TR 97–022 Mobility—Combat Mounted TR 97–037 Combat Vehicle Propulsion TR 97–040 Firepower Lethality TR 97–057 Modeling and Simulation
Advanced Manufacturing Demonstrations	TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–022 Mobility—Combat Mounted TR 97–024 Combat Support/Combat Service Support Mobility

U. MODELING AND SIMULATION

1. Scope

The Army modeling and simulation (M&S) technology program is focused on technology development in the three management domains of (1) training, exercise, and military operations (TEMO), (2) advanced concepts and requirements (ACRs) generation, and (3) RDA. The first domain addresses the Army operational requirements to support Force XXI and beyond and other simulation applications, where interoperable, distributed simulations—live, constructive, and virtual—at geographically separated locations are connected to form realistic synthetic environments. The other two domains are concerned with Army institutional requirements to develop, generate, project, and sustain the force. Complex and dynamic problems of requirements definition and analysis, S&T, acquisition and prototyping, test and evaluation, production and logistics, training and readiness, and military operations must be simulated in the scale and resolution essential for the battlespace.

M&S technology development is carried out throughout almost all budget activities, making a distinction of efforts by program elements dubious. This chapter focuses on M&S technology developments customarily associated with 6.2 activities, but not necessarily carried out under 6.2 category funding.

2. Rationale

The Army Science Board (ASB) 1991 *Study on Army Simulation Strategy* unequivocally conveyed the reality, "Increased automation of our forces and materiel, including its acquisition and operational utilization, provides the highest payoff potential as a force multiplier to offset the ongoing force reduction."

To optimally exploit the opportunities offered by the emerging automation technologies, the ASB put forward the concept of the EBF. This concept has been adopted by the Army. The long-term objective of the EBF concept is to develop and implement a single, comprehensive system of synthetic environments for operational and technical simulation that can support combat development, system acquisition, developmental and operational test and evaluation, logistics, training, mission planning, and rehearsal in Army specific and joint operations.

A watershed event for DoD and Army M&S was the designation of the HLA as the standard technical architecture for all DoD simulations. In an effort to move toward execution of this policy, each service is reviewing all of its simulation projects and programs and establishing plans for near-term compliance.

The near-term priority—establishment of the simulation infrastructure—is being addressed by the Army Digitization Office and the Force XXI initiative. To ensure timely M&S support, the Army has streamlined its M&S management by establishing the Army M&S General Officers Steering Committee co-chaired by the Vice Chief of Staff, Army (VCSA) and the Army Acquisition Executive (AAE), the Army M&S Executive Council co-chaired by the Deputy Chief of Staff for Operations and Plans (DCSOPS) and the Deputy Under Secretary of the Army (Operations Research (DUSA(OR)), and the Model and Simulation Office, which oversees all major Army M&S activities through the three management domains.

3. Management Domains

The majority of M&S technology base developments support multiple domains. To use the Army M&S management structure but avoid repeating common technology developments at multiple places, the capability requirements to be provided by the technology base are summarized in the individual management domains, and the S&T programs that are needed to attain these capabilities on a timely basis are described in the M&S subareas of the DTAP information systems and technology area.

a. Training, Exercise, and Military Operations

Army M&S technology development in support of the Force XXI combined arms training strategy (CATS) is the responsibility of the Simulation, Training, and Instrumentation Command (STRICOM) and is discussed in Chapter VI. Technologies must be provided that will enable substantially expanded use of simulators and simulations to train the soldier in a seamless synthetic environment as part of crew drills, routine deployment exercises, and live fire exercises.

Army M&S technology base development in support of military operations is coordinated by CECOM. The Army space and missile defense M&S technology development and technology base development are the responsibility of the Space and Missile Defense Command (SMDC). Technologies must be advanced that provide faster than real time interactive, predictive, continuous running simulations in support of dynamic automated planning and execution control systems to increase the tempo of operations of the integrated force and enable the most efficient use of all resources—mobility, power projection, operations, and people. The following elements are key:

- A flexible, secure, and situation-dependent interaction of the users with the synthetic environment, supported by intelligent systems that:
  - Emulate human-like thought processes
  - Learn and adapt to user needs
  - Make optimal use of commercial operating systems, network protocols, and programming languages.
- Multimedia knowledge sharing and management throughout the operational hierarchy, including situational awareness and resource databases.
- An open-ended design of the dynamic planning and execution control system architecture.

b. Advanced Concept and Requirements Generation

Army S&T in this domain mainly supports brigade and below echelon aspects of the tactical force and materiel modernization requirement analyses, while simulation technology development for strategic, operational, and upper echelon tactical force analyses is addressed by DARPA. The Army space and missile defense ACRs are the responsibility of the SMDC. M&S technologies must be advanced that will foster the realistic simulation of structure, employment and tactics, dynamics, and performance of organizational and materiel unit building blocks in a combined arms environment with the level of details and fidelity, parameter variations, and statistical accuracy specified by analysis and concept definition requirements and within the action/response times of the interacting live simulation constituency.

c. Research, Development, and Acquisition

This domain, coordinated by Army materiel systems analysis activity (AMSAA), provides the technology base for the two preceding domains and the acquisition of materiel. The Army space and missile defense RDA is the responsibility of the SMDC. Technologies have to be advanced that will enable embedding the total technology development and materiel acquisition process, from cradle to grave, in a system of networked synthetic environments that can seamlessly be linked with each other and the other domains. This includes technology base development, concept formulation and evaluation, ATD, DEM/VAL, EMD, production, upgrade, demilitarization, and associated processes such as T&E, operational T&E (OT&E), logistics support assessment, cost estimation, performance and cost tradeoffs, scheduling, cost and progress monitoring, and program management.

4. Technology Subareas

M&S is an information technology subarea—information is used to generate new knowledge from available knowledge via modeling and simulating logical interrelations. This is manifested in the 1998 DoD DTAP where decision making, M&S, information management and distribution, seamless communications, and computing and software technology make up one technology area—information systems and technology (IST). To provide ASTMP-to-DTAP connectivity, the M&S structure of the DTAP IST—simulation interconnection, information, representation, interface, and individual combatant and SUOs—is maintained and interrelated to the ASTMP technology areas.

a. Simulation Interconnection

This subarea is concerned with the architectural design, protocols and standards, MLS, survivability, interoperability among simulations at different levels of resolution, and common services (application gateways, databases, time and workload management, servers, and translators) to conduct collaborative simulations over the information network. The Army relies mainly on DARPA and on private enterprise for technology advancements. Army M&S S&T programs on information network architecture and infrastructure for distributed M&S are delineated in Sections IV–G and IV–H.

Goals and Timeframes

The goal is to provide interoperability for on-demand synthetic environments. This includes the HLA, which governs the synergistic formation and evolution of individual simulation infrastructures—live, constructive, virtual—and the systems and subsystems and simulation management. The baseline HLA is defined by three interrelated elements: HLA Rules Version 1.0 (v.1.0), HLA Interface Specification v.1.0, and HLA Object Model Template v.1.0. Evolution of the HLA will be managed by the DoD Executive Council for Modeling and Simulation (EXCIMS) through its Architecture Management Group (AMG). This structure provides a means for the DoD components to identify and address any remaining or emergent issues in subsequent refinements to the HLA baseline. The architecture must enable a user friendly, intelligent, object-oriented, graphical environment. The baseline HLA gives impetus to the development of cost-effective methods for verification, validation, and accreditation (VV&A) and ensures military utility of the evolving HLA and the networked synthetic environments. VV&A of DIS/HLA applications is a major Army M&S focus. We must determine whether VV&A of an aggregated system is the sum of the VV&A of its parts. Network accessibility and portability of existing databases across all environmental domains and automatic multilevel exchange of multimedia information should become available by the end of this decade. Very large scale distributed simulation with adaptive, dynamic network resource allocation and distributed multimedia knowledge sharing at all classification levels will be possible for all three domains by the end of the next decade.

The Army, through STRICOM, has DoD responsibility for DIS standards and protocols and, thus, plays a major part in their development. Now that HLA is the DoD standard architecture, the standards developed and lessons learned for DIS environments will transfer from DIS applications to non-DIS and HLA applications. DIS is not a subset of HLA, but there is considerable overlap between the two. The goal is to make this migration from DIS to HLA seamless and successful. Until the DoD synthetic environment technical reference model becomes available, building blocks will rely on DIS-based protocols between simulation infrastructures to supply the functional network control and management. DIS-related programs are contained in Chapter VI.

Major Technical Challenges

Algorithms, models, associated software, and even databases lack connectivity and real-time information processing capability, and the run time infrastructure for HLA is still evolving.

Architectural design, protocols, standards, and MLS are required to maximize interoperability among simulations at different levels of resolution. The unavailability of mathematical algorithms to automate the conversion of discipline-specific simulation systems and subsystems for use in synthetic environments on a heterogeneous communications and computation network is a technical barrier.

b. Simulation Information

This subarea addresses development of common conceptual models of mission space (CMMS) using authoritative representations to provide DoD users the ability to cost effectively develop simulations providing consistent and reliable results with the objective of providing warfighters worldwide access to conceptual models of DoD processes.

These tasks are inherently scenario-dependent, multistep, multifaceted, hierarchical processes involving complex evaluations at different information aggregate levels. Current planning capability is cumbersome, manpower intensive, time consuming, and judgmental. The infrastructure to support rapid automated mission planning, simulation-embedded mission rehearsal, and real-time simulation-aided execution management aids is evolving through the digitization of the battlespace. Missing are the computational methods, AI algorithms, architecture, logical relations, and associated software that are necessary for the formulation and evaluation of scenario-dependent, complex military situations in the context of higher level command and control instructions and within the operational tempo. While DARPA is the major player in advancing technologies for simulation-based tactical decision making, Army S&T concentrates on their application and filling the gaps.

Goals and Timeframe

The long-term goal of this subarea is to provide the synthetic environments for automation-assisted C^2 throughout the evolving C^4I infrastructure. While near-term emphasis is on information overload reduction, mid-term emphasis is on mission and route planning for lower echelon assets and aggregation of the individual plans into integrated company and battalion level plans. This also includes mission sustainment (e.g., logistics, maintenance and repair, soldier services).

Computer-generated forces (CGF) requires representation of human (soldier) behaviors for a realistic simulation of system performance. Individual soldiers, groups of soldiers (units / crews), single weapon platforms, and units of platforms must be simulated as aggregated and disaggregated entities. The goal is to represent adaptive, interactive, "intelligent" behavior of soldiers, units, platforms and smart weapons in variable scale realistic synthetic environments. The primary development and application of CGF for the Army is promulgated in the evolution of modular semiautomated forces (ModSAF) through the cooperative efforts of AMC and DARPA. Currently, there are several "flavors" of semiautomated forces (SAFs): ModSAF, ModSAF variants, and close combat tactical trainer (CCTT) SAF, as well as other CGFs such as interactive tactical environment management system (ITEMS), Janus linked to DIS (JLINK) and joint conflict model (JCM). Future efforts will be directed toward developing a SAF system that will meet next generation M&S requirements from all three M&S domains; this effort is referred to as OneSAF. Ongoing Army S&T includes modeling systems and subsystems in computer software, interaction among the models and with other components of the simulation environment, and integration to support near- and mid-term operational requirements. SMDC missile defense simulation activities will continue to provide extended air defense testbed (EADTB) and extended air defense simulation (EADSIM) to authoritatively simulate the missile defense systems, architecture and battle management (BM) C^4I necessary for Army studies and training exercises.

Computation-aided operational planning requires algorithms that translate military C^2

instructions into computer language and integrate these with battlespace environment, battlespace situation awareness information, and mission specific doctrines. Predictive, networked, simulation-based planning will be possible within the next 15 years.

Computation-aided mission rehearsal requires the same technologies and databases as mission planning, as well as virtual reality. Within the next 15 years, technologies will support implementation of materiel embedded training, where individual units and their aggregates are fully immersed in synthetic environments, with horizontal and vertical synchronization throughout the operational forces in the rehearsal using in-place equipment.

In order to increase automation in operational execution control management, AI technologies are needed that speed up and improve decision, C^2, and information flow processes based on situation and resource knowledge. This includes technologies for automated revision of mission and route plans for the fighting units as well as their support, area-controlled, hierarchical information management over combat communications networks, and application-tailored information display and network interface. Near-term emphasis is on providing information management technologies tailored to the needs of the digitized battlefield infrastructure. Model and computation optimization technologies and use of scalable massively parallel processors will enable dynamic, simulation-assisted, C^4I node execution control management within the next 10 years, followed 5 years later by adaptive management that is fully coordinated throughout the battlespace.

Major Technical Challenges

Advances in both hardware and software allow for higher resolution and fidelity representation of M&S synthetic force applications. This level of detail requires a significant increase in personnel to "control" these entities within the simulation. There is a need for synthetic forces to conduct their own C^2 functions and behave in a validated manner. Modeling cognitive human behavior is emerging as one of the most important leading edge needs for future M&S applications.

Future synthetic forces must perform course of action analysis, and mission, enemy, troops, terrain and time (METT–T) analysis without human intervention. When fully developed, synthetic forces will be capable of generating operations orders at multiple echelons, dependent on the orders they receive from higher echelon synthetic forces. In order to meet this challenge, the Army must pursue work that advances the state of the art in collecting, verifying, validating, and storing information and data that enable cognitive reasoning modeling.

Although progress has been made in some simulation areas, the technologies are not yet completely available to enable fast and situation-adaptive operational planning with optimal use of resources throughout the hierarchical task force structure, including support elements. Of particular challenge are operational rehearsal (and training) of force components in a virtual environment that projects the most likely battlespace situation and operational execution, with intelligent system-aided C^2 oversight. Both must be able to quickly adjust mission plans to changing situations. Algorithms must be advanced for integrating the individual synthetic environments (e.g., for elements of the operating forces and their support) into an aggregate system and for scaling the CGF and support from entity level through any level of hierarchical echelon, while preserving the dynamics and behavioral aspects of aggregation and disaggregation. Also, realistic/trustworthy accounting and forecasting of the state and ability of human resources—ours as well as the foe's—are necessary. This includes the effect of battlefield stress on human performance and casualty and incapacitation from battlefield hazards.

Materiel Acquisition

DoD policy requires that all new major system developments be carried out embedded in

open architecture simulations, using DoD-specific and COTS engineering, software engineering, and life-cycle management tools to reduce acquisition time and life-cycle cost. M&S S&T in support of engineering designs and analyses are intrinsic parts of the noninformation technology areas and described in that discussion. Development of technologies to integrate individual M&S software for system design and manage the engineering process is mainly commerce driven, with active participation of Army RDECs and the SMDC in their area of acquisition support responsibility.

Goals and Timeframes

The long-term goal is to establish a capability to produce synthetic prototypes of systems with complete electronic documentation of the products, engineering models, and software tools used, manufacturing and assembling instructions, and performance.

In support of ACR, M&S technologies are being developed that will provide, within the next decade, the capability to:

- Remotely access expert repositories at RDECs, battle laboratories, and other organizations, including industry.
- Search for and retrieve operational and technical models and databases pertinent to the concept to be evaluated.
- Integrate this information, in a synthetic environment, into candidate systems with operational performance and technology exploitation optimized to the available acquisition resources.

Rudimental systems are already in place to integrate realistic synthetic system mockups (virtual prototypes) into operational simulation environments via DIS.

In the materiel development, engineering, and production area, technologies are required that allow highly automated utilization of engineering models in the design of components and their integration into a system, employing concurrent, automated software configuration management with or without physical simulators in the loop, in support of and tailored to the development of specific materiel or ATDs in both the tactical and the strategic arena.

Considerable progress has been made by the Army RDECs, the Air Force Manufacturing Technology Directorate, DARPA, the National Institute of Standards and Technology (NIST), and other organizations in developing and demonstrating virtual prototyping and manufacturing for application-specific problems. These technology advances are now being exploited in various Army M&S projects to systematically formulate the process of designing and building simulation substructures in a modular fashion with adaptable, flexible interfaces. Emphasis is on simulating the manufacturing process of materials, their machining into components, and their assembly into virtual prototypes.

The Army S&T programs in support of this area are detailed in Sections IV–P and IV–T.

T&E of the design and performance of components, subsystems, and systems are an integral part of the materiel acquisition process. Even though physical simulators are increasingly used for components, hardware, and software in-the-loop testing, the current T&E methodologies are nevertheless labor, time, and cost intensive and do not support the concept of rapid configurational prototyping through synthetic environments. The virtual proving ground, now in development by the Test and Evaluation Command (TECOM), will (1) increase the synthetic environment capability for components simulation, (2)shorten the human in-the-loop design, test, and fix cycle, and (3) enable networking of T&E, OT&E, and other databases. Ongoing S&T work supports the development of a flexible open architecture that will seamlessly link constructive, virtual, and live T&E simulations.

Major Technical Challenges

Apart from technologies for the synthetic operational environments, the development, engineering, and manufacturing M&S technolo-

gies and tools used in the acquisition process are basically the same as for similar commercial products. Most of the tools are standalone software packages lacking open architecture; hence, software and repository integration into domain-specific synthetic environments and their embedding in an integrated, networked acquisition process and management environment is a tedious and difficult endeavor.

The technical simulation models in use today are mainly general scientific and engineering analysis computer programs for application-specific system components and physical processes. The majority lack rapid interconnectivity with each other and with operational M&S and require software reengineering for efficient use on parallel processors. To replace the current prototyping/testing approach with virtual prototyping, and thereby attain the potential large savings in cost and development time, the evolving methodologies—first principle models, performance data prediction, and system simulation—must first undergo a rigorous VV&A process.

c. Simulation Representation

This subarea is concerned with technologies that will enable, within the time of operational decision cycles, generation and realistic synthetic representation of the prevailing physical environment, natural and manmade (e.g., terrain, hydrography, atmosphere, vegetation, buildings), the materiel and humans operating in it, and their interactions with each other. The M&S programs that constitute the prevailing physical environment and enable its display are described in Sections IV–M and IV–N.

Goals and Timeframes

The synthetic physical environment must be accurate, realistic, and capable of rapid updating to provide a sense of normal time flow during a simulation process across a wide variety of M&S systems.

The fundamental technologies necessary for integrating maps from distributed environmental databases, information on current weather and from battlefield situation awareness, and simulation-based assessments of tactical movements put forward by C^4I node staff into an aggregate dynamic environment and presenting it into mission specific spatiotemporal 3D scene projection have been developed for virtual sand table applications.

Interactive, high-fidelity environment and force representations will be possible within 15 years. Efforts are under way to automate the generation of electronic environment databases and to increase their spatial resolution to digital terrain elevation data (DTED) level II (10 meters). This database will comprise digital maps for terrain, soils, roads, drainage, foliage, and other environment characteristics. High-fidelity, full-spectrum weather models for the evolution of the environment and its effect on individual system performance should be realizable within the next decade (FY05). Realistic human/group behavior representation under battlefield conditions will be possible within 10 to 15 years.

Major Technical Challenges

All sensors, including humans, are impacted by environmental conditions. Unavailability of valid environmental data in the resolution required for each combat system is a major barrier to achieving realistic simulation. Multimedia knowledge sharing of environmental information between distributed heterogeneous databases is still unresolved. The lack of mathematical algorithms and corresponding software to represent a "real" physical environment represents a major barrier. To overcome this barrier we need to reduce the time and cost of database development, harness computational performance for dynamic environmental representation, and maintain consistency across models of varying resolution.

The lower echelon combat C^4I nodes will be overloaded with information and, thus, may be unable to make all the logical decisions necessary to effectively implement higher echelon C^2. Intel-

ligent systems with automated reasoning emulating the human thought process must be advanced that provide battlefield (human) decision makers, especially in stressful environments, with information that they need when they need it without overwhelming them.

d. Simulation Interface

This subarea addresses the development of technologies that will enable a quick and responsive interface between the human and synthetic environments and realistic dynamic representation of systems in synthetic environments and of synthetic forces to the human.

Goals and Timeframes

The goal is to provide simulation interfaces for seamless integration and composability of federations of M&S applications with live systems, instrumented systems on test/training ranges, and humans. Algorithms and associated software that connect the synthetic environment with the machine hardware and firmware that interfaces with the human are needed. When developed, they will allow the soldier to interact with the machine without distracting from the task to be performed. Human interfaces to provide the synthetic environment for soldiers and command staffs will further mature within the next 10 years; full immersion of the soldiers for rehearsal and as part of the operational execution, within 15 years.

Major Technical Challenges

Algorithms are needed to characterize sensory perception to support development of flexible and rapidly reconfigurable user interface stations that serve as input and feedback devices to the simulation network. Hardware and software are needed for high-resolution, real-time scene generation.

e. Individual Combatant and Small Unit Operation Simulations

This subarea is concerned with the development of high-level, architecture-compliant individual combatant simulation systems across the RDA, ACR, and TEMO domains. Live, virtual, and constructive simulations relevant and sufficient to model the individual combatant and small unit will be developed to reduce the time and cost of advanced concepts and prototyping of new soldier systems and to reduce the cost of training individuals and small units.

Goals and Timeframes

The goals are (1) to refine the RDA, ACR, and TEMO M&S requirements, (2) create a multisensory, real-time networked simulation of the battlefield that immerses the individual and small unit in 3D geographical space using virtual reality technologies, and (3) develop modeling, simulation, and analytic tools to facilitate the design and analysis of alternatives for the Land Warrior program. The subarea will provide a demonstrated capability to fully immerse the live combatant in the synthetic environment, to include control of semiautonomous forces, through voice and gesture recognition. Linkage of virtual, constructive, and instrumented live simulations to enable individuals and small units to participate in distributed combined arms exercises and experiments will be possible within 10 years; reduction of the cost associated with the design, testing and fielding of new soldier systems and reduced training costs will be accomplished within 15 years.

Major Technical Challenges

Focus will be on human representation and visualization of individuals and weapon states, human performance modeling, human systems interfaces that are unencumbered and elicit realistic performance, networked simulations for interoperability with dissimilar simulations, CGF that contain realistic individual and unit-level behaviors with C^4I representation, synthetic terrain with relevant resolution/fidelity to allow for operations in a tactically correct manner, and instrumentation for high-precision engagement simulation to allow for data capture and analysis.

5. Roadmap of Technology Objectives

The roadmap of technology objectives for Modeling and Simulation is shown in Table IV–42.

6. Linkages to Future Operational Capabilities

The influence of this technology area on TRADOC FOCs is summarized in Table IV–43.

Table IV–42. Technical Objectives for Modeling and Simulation

Technology Subarea	Near Term FY98–99	Mid Term FY00–04	Far Term FY05–13
Interconnection	DIS-based protocols and interfaces for M&S infrastructures Prototype high-level architectures Initial software reuse via domain-specific architectures and interfaces	Tools/models with connectivity and real-time information processing Cost-effective VV&A methodology for networked synthetic environments Database accessibility and portability across network with multimedia information exchange Open architecture software engineering environment framework with process support	Architecture and interface codification and validation Very large distributed simulations with adaptive network resource allocations and multimedia knowledge sharing Standard, automated linked substructure–system–subsystem descriptions based on functional and physical features
Information	Methods to reduce information overload at C^4I nodes Extensive AI planning and decision support for computer-generated forces Software technology for adaptable, reliable systems (STARS)	Automated mission and route planning for lower echelons Scalable object-oriented database management and information models Algorithms/tools for modular design of M&S substructures with adaptable, flexible interfaces	Predictive, networked, simulation-based planning and C^2 management Adaptive, dynamic resource allocation for very large scale distributed simulation Concurrent analyses of products and processes for prototyping and manufacturing by distribution teams
Representation	High-resolution, real-time scene generation Automated generation of electronic environment databases (maps)	High-resolution, real-time infrared/multisensor scene generation Mission-specific, spatiotemporal scene projection of aggregate dynamic battlespace environment	High-fidelity, full-spectrum weather evolution models Highly interactive, high-fidelity force and environment projection Realistic human/group behavior
Interfaces	High-resolution, wide field of view night vision	3D volumetric view with 3D audio Color helmet display	Human-like interaction with synthetic environment Full immersion into synthetic environment

Table IV–43. Modeling and Simulation Linkages to Future Operational Capabilities

Technology Subarea	Integrated and Branch/Functional Unique Future Operational Capabilities
Interconnection	TR 97–001 Command and Control TR 97–002 Situational Awareness TR 97–003 Mission Planning and Rehearsal TR 97–007 Battlefield Information Passage TR 97–009 Communications Transport Systems TR 97–011 Information Services TR 97–012 Information Systems TR 97–013 Network Management TR 97–015 Common Terrain Portrayal TR 97–016 Information Analysis TR 97–017 Information Display TR 97–053 Embedded Training and Soldier–Machine Interface TR 97–054 Virtual Reality TR 97–055 Live, Virtual, and Constructive Simulation Technologies TR 97–056 Synthetic Environment TR 97–057 Modeling and Simulation
Information	TR 97–001 Command and Control TR 97–002 Situational Awareness TR 97–003 Mission Planning and Rehearsal TR 97–007 Battlefield Information Passage TR 97–009 Communications Transport Systems TR 97–010 Tactical Communications TR 97–011 Information Services TR 97–012 Information Systems TR 97–013 Network Management TR 97–016 Information Analysis TR 97–017 Information Display TR 97–018 Relevant Information and Intelligence TR 97–019 Command and Control Warfare TR 97–020 Information Collection, Dissemination, and Analysis TR 97–053 Embedded Training and Soldier–Machine Interface TR 97–054 Virtual Reality TR 97–055 Live, Virtual, and Constructive Simulation Technologies TR 97–056 Synthetic Environment TR 97–057 Modeling and Simulation
Representation	TR 97–003 Mission Planning and Rehearsal TR 97–015 Common Terrain Portrayal TR 97–016 Information Analysis TR 97–017 Information Display TR 97–020 Information Collection, Dissemination, and Analysis TR 97–052 Training Aids, Devices, Simulators, and Simulations Fidelity Requirements TR 97–053 Embedded Training and Soldier–Machine Interface TR 97–054 Virtual Reality TR 97–055 Live, Virtual, and Constructive Simulation Technologies TR 97–056 Synthetic Environment TR 97–057 Modeling and Simulation
Interfaces	TR 97–003 Mission Planning and Rehearsal TR 97–006 Combat Identification TR 97–017 Information Display TR 97–020 Information Collection, Dissemination, and Analysis TR 97–021 Real-Time Target Acquisition, Identification, and Dissemination TR 97–028 Unmanned Terrain Domination TR 97–052 Training Aids, Devices, Simulators, and Simulations Fidelity Requirements TR 97–053 Embedded Training and Soldier–Machine Interface TR 97–054 Virtual Reality TR 97–055 Live, Virtual, and Constructive Simulation Technologies TR 97–056 Synthetic Environment TR 97–057 Modeling and Simulation

CHAPTER V

BASIC RESEARCH

CONTENTS

CHAPTER V

BASIC RESEARCH

Without strong basic research, the foundations for the development of future technologies will not be laid.

STAR21, National Research Council

A. INTRODUCTION

The Army is the full spectrum land warfighting force of the United States. In order to maintain an overmatching capability on which the U.S. depends, the Army invests in basic research to provide this force with technological superiority. Fundamental research is the "seed corn" for technological discoveries and advancements. The Army's basic research:

- Fosters progress and innovations in Army-unique areas (e.g., armor/anti-armor) or where commercial incentive to invest is lacking due to limited markets (e.g., military medicine to develop vaccines for tropical diseases).
- Shapes research and technological innovations concerning issues related to Army applications/environments.

In this way, the Army can develop or adapt its technology needs for the ever-increasing variety of missions it faces. The Army's dependence on technology is increasing as it evolves toward smaller, lighter, more lethal forces. The investment made in basic research today will shape the future Army by providing the technological building blocks needed to address imperatives emerging from future warfighting concepts.

Senior Army management is committed to a sustained basic research program that supports the Army's needs. To this end, the Army structures a coherent basic research program and integrates extramural research that leverages the power of academia and industry with in-house research in critical, Army-unique areas. The resulting science base provides the foundation for follow-on applied research (6.2) and, eventually, advanced technology development (6.3) programs.

The Army research program is managed and performed by a network of Army laboratories and centers. Within the **Army Materiel Command** (AMC) the Army Research Office (ARO) manages extramural programs through the University Single Investigator program, selected centers of excellence (COEs) and the university research initiative (URI) programs. The Army Research Laboratory (ARL) supports several Centers of Excellence, manages the federated laboratories, and conducts in-house research. Finally, the research, development and engineering centers (RDECs) initiate research through the In-house Laboratory Independent Research program. The **Army Medical Research and Materiel Command**, **Army Corps of Engineers**, and the **Army Research Institute (ARI) for Behavioral and Social Sciences** also conduct a mixture of intramural and extramural research programs as shown in Table V–1.

Without the scientific base developed by these activities, the Army would not have in its arsenal many technologies that are now taken for granted and that have been used effectively in

Table V–1. Basic Research Responsibilities of Department of Army Components

Army Component	Basic Research Mission	Research Emphases	Execution Strategy
Army Materiel Command	Conduct and sponsor basic research unique to Army requirements (that are not covered by the Army Corps of Engineers, Army Medical Research and Materiel Command, and ARI) and areas assigned to AMC through the Department of Defense (DoD) in support of other agencies Ensure that basic research supports future warfighting requirements Making technology work for soldiers	Lethality Energy efficiency Lighter, smaller components Protection and survivability Specific areas are: • Missiles • Vehicles (tracked and wheeled) • Guns and artillery • Aviation • Nuclear, biological, and chemical (NBC) defense • Nutrition/food sciences • Textiles • Testing • Sensors/electronics/communications • Simulation and training devices • Armor (personnel, vehicle, weapon systems) • Multispectral camouflage Mobility	Partnership with Training and Doctrine Command to focus on future warfighting doctrine and required capabilities Leverage industry, national laboratories, and academia Teams and consortia with national organizations Participate in international organizations AMC's ARO directs most long-term (theoretical and feasibility) efforts AMC's ARL directs most short-term (prototype and demonstration) efforts Move basic research successes from ARO and ARL to AMC research, development and engineering centers for systems application
Army Medical Research and Materiel Command	Exploit basic science to define potential biomedical solutions to overcome military-unique threats to health and combat health care delivery constraints, and maximize the operational performance of the warfighter	Infectious diseases of military importance Combat casualty care Army operational medicine Medical chemical and biological (CB) defense	Perform studies and exploit civilian basic biomedical research to define injury mechanisms of military health threats Maintain in-house expertise, including uniformed military medical scientists, to avoid technological surprise and maximize ability to meet military needs Selectively invest in critical extramural capabilities Leverage industry and other government agency programs, exploiting unique Army capabilities to facilitate discovery of dual-use technologies Maximize efficiency through tri-service coordination via the Armed Services Biomedical Research Evaluation and Management Committee

Table V–1. Basic Research Responsibilities of Department of Army Components (continued)

Army Component	Basic Research Mission	Research Emphases	Execution Strategy
Army Corps of Engineers	Conduct scientific research in disciplines associated with civil engineering, environmental sciences, and environmental quality that expands knowledge base and provides technical underpinning for exploratory research related to future operational capabilities for: • Mapping, terrain analysis, image processing, and radar exploitation • Effects of cold regions and winter weather on combat operations and stability and support operations (SASO) • Airfields and pavements for strategic and operational mobility • Next generation Army mobility models • Acquisition, operation, maintenance and repair of installations • Environmental quality	Signature analysis (radar and spectral analysis for data generation) Terrain analysis and reasoning Energy propagation in terrestrial environments Pavements and airfields Smart materials Hardened construction materials Multispectral materials for field fortifications and structures Vehicle–terrain interaction Hazardous/toxic waste remediation Hazardous wastewater management Quantifying impacts of military operations on natural and cultural resources Groundwater modeling	Identify and execute research efforts focused on future operational capabilities (FOCs) and concepts for AAN Establish and maintain liaison support to primary customers Identify specific technology areas that lend themselves to partnering with academia and industry Develop a resource strategy that supports both internal teaming and external partnering Transition basic research successes in a timely manner
Army Research Institute	Conduct scientific research that will support the development of people-related technologies: • Training: improve the long-term retention of trained skills and the potential of skills to transfer to real life • Personnel: improve recruitment, assignment, and Army's ability to address societal issues • Leadership: improve the assessment and development of skills	Training research Personnel research Leadership research	Aim research to future-oriented/AAN issues Coordinate research with applied scientists to increase chance of transitions Call upon world-class scientists for conduct of research

recent military operations around the world. The ultimate payoff of basic research is the translation of concepts into technological applications. Examples of applications that have evolved from Army basic research programs include:

- The concept of inverted populations of excited quantum states translated into a laser.
- Use of fast mathematical procedures to calculate Fourier transforms for fire support.
- Advanced materials from basic principles to yield required properties and performance.
- Incorporation of small, superfast electronic devices into systems.
- Precise atomic measurements transitioned to global positioning systems (GPSs).
- Nonlinear mathematical techniques that are the basis for secure Army communications.

- Mathematical simulation techniques yielding application-specific microprocessors for Army use.

The Army must be a versatile, mobile, deployable, power projection land warfighting force. To meet this objective the Army is increasing its dependence on technology to increase its lethality and survivability, decrease its logistics burden, maximize its situational awareness, lighten the force, and enhance soldier performance. To become technologically superior there is a continuous and essential emphasis on basic research in:

- Enabling breakthrough capabilities.
- Exploiting technological opportunities.
- Taking advantage of surprise technological discoveries.
- Interpreting and tailoring progress for the Army's benefit.

1. Army Basic Research Program

The Army basic research program is a critical and integral part of the Department of Defense (DoD) *Basic Research Plan* (BRP). This DoD BRP describes twelve scientific disciplines and formulates broad visions of what might be achieved in each of these disciplines. It also presents six Strategic Research Objectives (SROs) that define rapidly expanding research fronts with the potential for high military benefit.

The *Army Basic Research Plan* formulates Army-oriented programs in all but one (Ocean Sciences) of the DoD-recognized scientific disciplines, and it recognizes and plays a lead role in all six of the SROs. These Army programs and roles are detailed in following sections of this chapter.

The Army BRP is managed and executed to focus knowledge in areas critical to the Army. It initiates and fosters revolutionary research that is capable of providing innovative new opportunities for the future Army and evolutionary research responsive to identified needs. The level of investment is dependent on:

- Emerging technological opportunities.
- Future Army concepts and perceived needs.
- The ability to leverage investment for many applications and from other services/agencies.
- Commercial investments.
- Program continuity.
- Viable support for selected areas (e.g., SROs).

There is a tripartite approach to Army basic research that is based on complementary driving forces. These driving forces are:

- To exploit basic research opportunities and discoveries (revolutionary innovations).
- To pursue SROs, particularly those related to the *Army After Next* (AAN) doctrine (focused research).
- To maintain land warfare technical subdisciplines (evolutionary research).

The Army's basic research program maintains a balanced intramural/extramural effort to satisfy these driving forces. Sixty percent of monies funded are for extramural research to:

- Give leverage to the power of academia and industry.
- Focus world-class research on Army challenges.
- Allow for flexibility to capture new discoveries.
- Complement the intramural efforts.

Forty percent of the monies funded are for intramural research programs (Army in-house) that:

- Help maintain "smart buyer" capability essential to the Army.
- Give leverage to government-unique facilities.

- Support Army-unique niche efforts.
- Support world-class researchers in areas critical to the Army.

2. Future Outlook

As the Army enters the 21st century, doctrinal changes are envisioned that will exploit technological advancements. From the beginning of the next century to the year 2010, Force XXI and *Army Vision 2010* doctrines will shape the Army's warfighting capabilities, and technologies already unfolding will support these doctrines. Further into the future, in an effort to project the Army toward the year 2025, the Chief of Staff of the Army has established the AAN. In planning the Army's basic research programs, this AAN initiative provides additional focus for the overall program. A key role for the Army research program is to foster the fundamental research that will enable AAN initiatives. The AAN will benefit from all 6.1 basic research, including the SROs, because the discoveries of today are the enablers of tomorrow's technologies.

It has been recognized for some time that basic research has been and will continue to be critical to the success of the military. Comments on basic research made over 50 years ago by Dr. Vannevar Bush, 1963 National Medal of Science Recipient, are still valid today: "Basic research is performed without thought of practical ends, but it provides a means of answering a large number of important practical problems." William J. Perry, former Secretary of Defense, also stated, "We are not the only nation with competence in defense science and technology. To sustain the lead which brought us victory during Desert Storm . . . recognizing that over time other nations will develop comparable capabilities, we must . . . invest in the next generation of defense technologies." More recently, Dr. Anita K. Jones, Director of Defense Research and Engineering (DDR&E), emphasized that basic research "provides guidance to the services and defense agencies so that their combined research efforts may enable our primary customer—the warfighter—to gain military advantage in the future." The wonder of research is that you never know what you might discover.

The following sections of this chapter detail the Army initiatives that scope the Army's basic research program and the scientific research areas that execute it.

B. INITIATIVES

The Army's basic research program takes advantage of numerous Army and DoD initiatives. These initiatives not only help to support and orient funding for specific research areas, such as COEs, university research centers, and historically black colleges and universities (HBCUs) and minority institutions (MIs), but they also provide guidance for future Army needs such as the AAN and SROs. Those initiatives having the greatest impact on research programs are described in this section.

1. Centers of Excellence

COEs continue to be an integral part of the Army's research investment strategy, along with single investigator programs and Army laboratory research. Centers have proven to be effective in many application-oriented projects in areas such as rotary wing technology and electronics. Interdisciplinary research requires the joint efforts of many scientists and engineers and also often requires the use of expensive research instrumentation that is difficult for a single investigator to acquire. Center programs often couple the state-of-the-art research programs with broad-based graduate education programs to increase the supply of scientists and engineers in areas of Army importance.

The scientific research undertaken at each COE (and URI center, see below) is dynamic and continuously reviewed, using various inputs for assessing the quality of the programs. These inputs include reviews by executive advisory boards that represent high-level management of industrial and military organizations and by technical advisory councils that represent technical personnel from multiservice organizations. Table V–2 illustrates the composition of a typical

management and technical panel—in this case the Center for Intelligent Resin Transfer Molding for Integral Armor Applications.

Army COEs are active in the research areas summarized in Table V–3. This table identifies each COE research program, provides a list of participating universities, summarizes the scope of each program, and highlights future plans. Some of these centers have had significant collaborative participation by HBCUs and MIs, a trend that the Army will be encouraging for future COEs. In addition, industry will be encouraged to participate more in future Army COEs to leverage and synergize the investment in these collaborative efforts. Table V–3 notes COEs funded directly by the Army and also those managed by the Army but funded by DoD.

Table V–2. An Example of the Composition of an Executive Advisory Board and Technical Advisory Council for a Center of Excellence (here, the Center for Intelligent Resin Transfer Molding for Integral Armor Applications)

Executive Advisory Board	Technical Advisory Council
Chairperson, Director, ARL Materials Directorate	Chairperson, ARO, Materials Science Division
ARO, Director, Materials Science Division	ARL, ST, Materials Directorate
National Aeronautics and Space Administration (NASA) Langley, Director, Vehicle Structures Directorate	ARL, Scientist, Weapons Technology Directorate
MICOM, Technical Director	University of Delaware, Scientist, Composites Manufacturing Science Laboratory
Tank–Automotive and Armaments Command (TACOM), Technical Director	Edgewood Research, Development, and Engineering Center (ERDEC), Scientist
Soldier Systems Command, Chief of Staff	Tank–Automotive Research, Development, and Engineering Center (TARDEC), Chief, Manufacturing Technology Branch
	McDonnell Douglas Missile Systems, Senior Group Manager—Composites
	Lockheed Martin, Manager, Advanced Programs
	United Defense Ground Systems, Manager Composite Structures

Table V–3. Army Centers of Excellence

Research Areas/ Participating Universities	Scope	Future Plans
	Army Funded	
Scientific Foundations of Image Analysis Washington University	Mathematical and algorithmic foundations of image science Fundamental performance limits on ATR systems Detection and recognition bounds	Hibert Schmidt orientation bound Orientation bounds for fused data
Science, Engineering, and Mathematics (SEM) Education* Contra Costa College	Coordinated program to increase number of underrepresented graduates in SEM Prescribed, sequential coursework Mentoring and study groups Internships and summer programs Includes tuition and stipend Outreach programs	Enroll 250 students over a 5-year period in science/mathematic programs Provide solid foundation in science and mathematics Facilitate transfer to institutions awarding higher degrees Encourage careers in SEM
Advanced Batteries and Fuel Cells* Illinois Institute of Technology Consortium	Electrochemistry Advanced material synthesis Manufacturing capability	Lithium/metal oxide batteries Nickel hydride batteries Direct oxidation methanol fuel cells

Table V–3. Army Centers of Excellence (continued)

Research Areas/ Participating Universities	Scope	Future Plans
Automotive University of Michigan	Advanced ground vehicle simulation Vehicle dynamics and structures Advanced propulsion systems Human–hardware interface	Vehicle system optimization Military vehicle technology assessments Cost/performance tradeoff methodology
Microelectronics University of Maryland, College Park	Nanoelectronics and optoelectronics CB detection Wide-bandgap electronics Integrated terahertz devices	Uncooled infrared (IR) sensors Optical interconnects Individual biodetectors High-speed signal processing
Johns Hopkins University	Piezoelectronics and electrochemistry Manufacturing science Microelectromechanics (MEM) High-resolution display technology	Microsensors New battery concepts New fuel cell concepts
University of Virginia	Integrated terahertz devices Quasi-optical electronics	High-speed signal processing Millimeter-wave (MMW) electronics
Howard University	Wide-bandgap electronics	High-temperature/high-power electronics Electromagnetic environment (EME) protection devices
Materials Johns Hopkins University	Advanced materials characterization Nondestructive materials evaluation Functional metal matrix composites Hydrogen interaction with materials	Joining of advanced materials Nonintrusive process monitoring Nanomaterials characterization
University of Delaware	Integrated composite armor materials Fiber resin interphase control Composite joining/adhesive bonding	High strain rate behavior and impact damage mitigation in composites Smart composite materials processing
Michigan Molecular Institute	Dendritic polymer materials Synthetic nanoscopic materials Synthesis, characterization, and assessment	Dendritic polymer scale up and engineering properties database Fiber coatings Conducting polymers Nanocomposites
High Performance Computing Research University of Minnesota	Efficient algorithms Large-scale scientific computing Efficient utilization of high-performance architectures	Parallel algorithms for novel architectures Large-scale scientific computing High-performance computing Adaptive gridding Mesh moving Multidisciplinary modeling Computational environment development

Table V–3. Army Centers of Excellence (continued)

Research Areas/ Participating Universities	Scope	Future Plans
Rotorcraft Georgia Institute of Technology	Efficient low-noise rotors Affordability Low-vibration dynamic systems Smart and composite structures Day/night adverse weather capability Integrated flight controls	Near-wake definition, aeroacoustics Slotted and circulation control rotors Aeroelastic and stability analysis; carefree flight control Finite element analysis of composite rotors Strength and life of damaged composites Wake-lifting surface interaction; dynamic inflow Robust and adaptive flight controls
University of Maryland	Low-vibration dynamic systems Smart and composite structures Day/night adverse weather Highly reliable, safe operations	Elastomeric dampers and bearings Vibration reduction and stability augmentation Concurrent design of composite rotors Low-noise fuselage panels for cabins Wireless rotor control, sensing and anti-icing
Pennsylvania State University	Efficient low-noise rotors Low-vibration dynamic systems Advanced drive trains Smart and composite structures Highly reliable, safe operations	Active control of noise, aeroacoustics Active/passive control of damping Vibration and loads; computational fluid dynamics Repair composite structures; active control systems Reconfigurable flight control systems
Information Sciences Clark Atlanta*	Distributed databases Probabilistic modeling Multimedia software Software reusability Computer optimization	Heterogeneous databases Models for software Interactive data analysis
Hypervelocity Physics and Electrodynamics Research Institute for Advanced Technology, University of Texas at Austin	Fundamental understanding of hypervelocity (HV) launch, flight, impact and lethality Rail/armature and launch effect electrodynamics Fundamentals of pulse power for electric armaments Supporting educational and assessment activities	Validate superior performance of HV projectiles Armatures and rail materials for robust, efficient launchers Support to pulsed alternator development, alternative pulse power approaches
	DoD Funded	
Advanced Distributed Simulation Grambling State University Consortium*	Parallel and distributed computing Heterogeneous multimedia database Interactive graphics and visualization	Advanced distributed simulation Student training and education program Enhance research infrastructure Man–machine interface

Table V–3. Army Centers of Excellence (continued)

Research Areas/ Participating Universities	Scope	Future Plans
Intelligent Resin Transfer Molding for Integral Armor Applications Tuskegee University* Consortium	Intelligent resin transfer molding for integral armor applications Resin transfer molding (RTM) process/ manufacturing, sensing and control New developments process modeling/ phenolic resins Bonding, repair, and ballistic performance	Smart weave and sensors in RTM Virtual manufacturing of RTM process Materials and process issues for integral armor Performance modeling, simulations, and testing
Science, Engineering and Mathematics (SEM) Education Morehouse College*	Unifies multiple departments to enhance programs and increase underrepresented graduates in SEM Summer study, field trips Mentoring/research programs Scholarship and outreach programs	Enhance quality of science and mathematics instruction in secondary schools Increase majors in SEM Increase number of graduate students in SEM Encourage careers in SEM

*Historically Black Colleges and Universities and Minority Institutions Centers

2. DoD University Research Initiatives

The Office of the Secretary of Defense (OSD) continues to support a portfolio of programs characterized as URI. All DoD services share the funds for this portfolio, nominating and investing in subject areas and activities best correlated with their research and technology needs.

A series of 5-year block grant URI programs, most funded at about $400,000 per year, concluded in FY96. Over 30 university groups performed research for the Army on topics in biology, advanced propulsion, materials, high-frequency microelectronics, electro-optics, nanotechnology, energy, manufacturing science, environmental sciences, and intelligent control systems.

During each year since FY94, several new 5-year multidisciplinary university research initiatives (MURIs) programs have been started, most funded at about $1 million per year. The MURIs typically engage two or more science/ engineering departments within a university (sometimes with other academic or industrial partners). Achievements not attainable through work in a single specialty are sought. For example, new levels of intelligence in control of rotor blades requires the collaborative expertise of investigators in mathematics and computer science as well as in the fields of aerodynamics and aerostructures. For another example, successful experiments with extremely small turbine engines require the collaborative expertise of investigators in propulsion as well as in manufacturing science, and perhaps other fields. Table V–4 lists the Army MURI centers, the scope of their research programs, and future plans.

In addition to the above, the URI program supports two graduate science and engineering education programs: the National Defense Science and Engineering Graduate Fellowship Program and the Augmentation Awards for Science and Engineering Research Training Program. These programs make up the bulk of the ongoing URI program. Other URI activities supported in FY97 included the Defense Experimental Program to Stimulate Competitive Research, the Infrastructure Support Program for HBCUs and MIs, the Defense University Research Instrumentation Program, the Focused Research Initiative, and a Young Investigator Program.

In addition to the technical programs and resulting accomplishments of the URI and COE efforts, another major output from these Army-funded academic programs is the support and graduation of technical students—many of whom go on to work in Army laboratories or allied industries.

Table V–4. Army Multidisciplined University Research Initiative Centers

Research Areas/ Participating Universities	Scope	Future Plans
	Terminating in FY1999	
Micro Gas Turbine Generators Massachusetts Institute of Technology	Develop high power, high energy density power sources Develop high aspect ratio fabrication of silicon carbide (SiC) Very small, high speed electrostatic generators Very high speed bearing systems	Very compact turbo compressors Compact recuperator systems Microcombustors for hydrocarbons
Smart Composite Structures Massachusetts Institute of Technology	Develop advanced technologies for the control of electromechanical systems Investigate solid-state actuator and sensor technologies and structural control for critical rotorcraft applications	Active materials technology Active composites mechanics and manufacture Distributed control technology Applications testbed program
Mesoscale Patterning For Smart Material Systems Princeton University with Harvard University and Drexel University	Mesoscale (1 nanometer (nm)–1 millimeter (mm)) patterning Laser stereolithography Self-assembled monolayers and templates	Microcontact printing of ferroelectric ceramics 3D coassembly of composites Mechanical characterization of patterned structures
High-Performance Fuel Cells University of Minnesota	Improved anode electrocatalysts for direct oxidation of methanol Improved membranes with low methanol permeability Develop a model for small fuel cells	Develop lower cost materials with sufficient lifetimes for military applications Develop methodology to functionally tether homogeneous catalysts to electrode structures Develop catalysts for direct oxidation of alkanes
Innovative Mesoscale Actuator Devices for Use in Rotorcraft Systems University of California, Los Angeles	Integration of ferroelectric actuator and silicon (Si)-based microelectromechanical system (MEMS) processing technologies Model and understand ferroelectric actuator behavior Investigate active control of dynamic stall and vibration reduction in rotorcrafts	Determine mechanical/tribological properties of MEMS structures Investigate high field, pulse mode operation of batteries Simulation of unsteady aeroelastic behavior of rotorblades
MEMS-Based Smart Gas Turbine Engines Case Western University	MEMS sensor/actuator arrays SiC-based MEMS structures Feedback control	Pressure, heat flux and ice detection sensors Flow control microvalves Computer-aided design (CAD)-based design High temperature sensors/actuators Distributed control
Thermophotovoltaic Electric Generator University of Western Washington	Develop robust IR emitters Improve power density of photovoltaic cells Develop filter technology required for improved efficiency	Develop high flux tailored spectrum emitters Improve long wavelength response of gallium antimonide (GaSb) photocells Improve burner technology for logistics

Table V–4. Army Multidisciplined University Research Initiative Centers (continued)

Research Areas/ Participating Universities	Scope	Future Plans
Terminating in FY2000		
Functionally Tailored Fibers and Fabrics Research North Carolina State University with Akron University and Drexel University	Functionally tailored textiles and fabrics Advanced fibers and polymers Multifunctional and smart materials Textile and textile-based composite manufacturing	Electrospinning of high performance fibers Clothing for comfort and battlefield threat protection Smart materials for camouflage, signature suppression, and soldier recognition Flexible and rigid armor composite materials design
Algorithmics of Motion University of Pennsylvania and Stanford University	Motion acquisition using computer vision Motion generation with planning algorithms Motion execution using control techniques	Automatic target recognition Reconnaissance and surveillance Navigation and mission planning Demining and data acquisition
Applicable and Robust Geometrical Computing Brown University, Johns Hopkins University, and Duke University	Geometric computing Development of robust algorithms Input/output (I/O) memory management	Terrain modeling CAD/computer-aided modeling (CAM) Geometric libraries and visualization software
Low Power, Low Noise Electronics University of Michigan with University of Colorado, Boulder University of California, Los Angeles with University of California, San Diego	Communications radio frequency (RF) components Radar RF components	Comprehensive low power design Power amplifier circuit interfaced with modulation/signal processing algorithms High functionality/low power devices High functionality/efficient antennas
Intelligent Turbine Engines Georgia Institute of Technology	Active control of gas turbines Sensors/actuators Control architecture	Combustor/compressor control MEMS sensors/actuators Dynamic engine models Nonlinear controllers
Terminating in FY2001		
Active Control of Rotorcraft Vibration University of Maryland	Exterior (rotor) noise and vibration control Interior noise control Transmission noise and vibration control	Mach-scaled rotor tests Comprehensive acoustic and vibration analysis techniques Innovative noise and vibration control concepts
Damage Tolerant Lightweight Armor Materials Purdue University University of Dayton Research Institute University of California, San Diego	Novel materials and structures design concepts Processing, fabrication, and testing of materials Advanced analytical methods	Layered, oriented, and gradient materials systems Dynamic viscoplasticity models for anisotropic materials Solution of inverse problems

Table V–4. Army Multidisciplined University Research Initiative Centers (continued)

Research Areas/ Participating Universities	Scope	Future Plans
Low Energy Electronics for Mobile Platforms University of Michigan	Top-down design methodology Optimization of all systems design levels Software implementation	Minimum energy information exchange Integrated platform system design Adaptive and minimum energy processing High performance devices and components
Photonic Band Engineering University of California, Los Angeles	Improved microwave/MMW devices Efficient microlasers and smart pixels Low observables and identification friend or foe (IFF)	Photonic crystals for electromagnetics Demonstrate low threshold lasing Nonlinear image processing
Integrated Approach to Intelligent Systems University of California, Berkeley	Design of hierarchical control architectures for multiagent systems Perceptual systems Framework for representing and reasoning with uncertainty Soft computing approaches to intelligence augmentation	Intelligence augmentation for human centered systems Fully autonomous systems Battle management
Demining Duke University University of Missouri, Rolla Northeastern University	Mine, ordnance, and explosive detection, identification, and location Sensor and information fusion Neutralization	Mine detection and location under realistic weather and environmental conditions Enhancement of detection probability Minimization of false alarm rate
Rapid, Affordable Generation of Terrain and Detailed Urban Feature Data Purdue University	Advanced photogrammetric and image understanding research Image understanding research for terrain analysis	Mathematical modeling for multisensor registration Automated extraction of remote sensing cues Automated feature recognition Unsupervised classification for hyperspectral imagery
Predictive Capabilities Based on Performance Metrics for Automatic Target Recognition for Military Applications Brown University	Quantitative understanding of ATR capabilities and limitations Metrics for structured clutter Metrics for scene complexity	Analytical frameworks for classifying images Algorithm-independent bounds on ATR performance Metrics to predict and measure the performance of ATR implementation
Biomimetics and Biomimetic Processing University of California, Santa Barbara	Biomimetic processing Mineralization in organic substrates Control of hierarchical structures	New EO devices Chemical detectors Structural materials New multifunctional and smart materials
	Terminating in FY2002	
Clustered Engineered Materials Northwestern University	Laser ablation/molecular beam cluster growth Nanosphere liftoff nanopatterning Self-assembled nanoclusters	Biological agent detection Photocatalysis for decontamination Efficient frequency conversion

Table V–4. Army Multidisciplined University Research Initiative Centers (continued)

Research Areas/ Participating Universities	Scope	Future Plans
Quasi-Optic Power Combining Clemson University California Institute of Technology	Spatial and quasi-optical power combining Hybrid power combining Array phase control Device/electromagnetic (EM) field interaction	Economical sources and arrays of MMW power Reduced size, weight, phase noise Enhanced reliability, durability Enhanced array functionality beam steering, modulation/demodulation, nonlinear function Reciprocal arrays, transmit and receive through common aperture
Design and Control of Smart Structures Harvard University with Boston University and the University of Maryland	Modeling and experiments with MEMS for flow control over airfoils Mathematical framework for modeling and controlling fluid motion Parallel array microvalves for flow control	Ferrofluidic micropumps for drug delivery MEM devices for flat panel displays Controlled deformable mirrors and antennas
Dendritic Polymers University of Illinois	Property discovery using combinatorial libraries Computational modeling to guide synthesis and properties Surface engineering and adhesion studies Synthesis and scale-up of polymeric materials	Responsive protective coatings and sensor coatings Catalysts for chemical agent destruction Volatile organic compound (VOC) free coatings Super-tough, processable elastomers Lubricants for solids and liquids
	Terminating in FY2003	
Defect Engineered Nanostructures Princeton University	Investigate fundamental issues Microscopically characterize structures Elucidate influence of defects on performance	Integration and mass production of quantum-based devices Reduce size and power consumption
Olfactory Sensing California Institute of Technology with Harvard University and Yale University	Characterize molecular events Model olfactory physiology Molecular recognition	Insight regarding olfactory processes Enable biomimetic approach Design and produce engineering systems
Adaptive Optoelectronic Eye University of Southern California University of Michigan	Manmade sensors that adapt and interact similar to animal vision Smart and adaptive emulation of biological eye Determine functionality of biological vision	Merge microelectronics, microoptic, and micromechanical devices Scheme for detecting, processing, and transmitting near-perfect optical images
Microthermal Engines Massachusetts Institute of Technology Georgia Institute of Technology	Understand and produce millimeter-sized devices to re-engineer traditional heat engines at mesoscale level Investigate new refractory ceramic micromachining Develop new bonding and micromolding	Power generation or cooling Replace batteries for individual soldier
Digital Communication Devices Based on Nonlinear Dynamics and Chaos University of California, San Diego	Generate digital signals by an integral nonlinear element, not a circuit or an integrated circuit (IC) Investigate simple microelectronic devices for control	Implement mobile wireless communication Secure digital transmissions with small, lightweight, low-power equipment

3. Historically Black Colleges and Universities and Minority Institutions

The AMC has set the pace for the DoD in programs for the HBCUs and MIs that share the goal of strengthening those institutions and enhancing their ability to participate in defense research, while preparing underrepresented minority students for the future, highly competitive S&T-oriented marketplace. The AMC is dedicated to increasing the participation of the HBCUs and MIs in all of its programs, particularly in the research and development (R&D) activities of the Army laboratories and RDECs.

The ARO has supported programs for the HBCUs and MIs since 1980. In addition, the ARO manages the DoD Infrastructure Support Program for these institutions. This special program has awarded over $97 million to them since it began in 1992, including over $38 million in grants to HBCUs and MIs to support collaborative research, instrumentation for research and education, COEs, and education centers for science, engineering, and mathematics (SEM). The HBCUs and MI COEs, supported by DoD funds under ARO grants, are conducting long-term research programs in Advanced Distributed Simulation and Intelligent Resin Transfer Molding for Integral Armor Applications (see Table V–3).

In addition to the DoD-funded centers, two other HBCUs or MIs are supported by ARO funds. These include a research consortium for Fuel Cell Battery Research, led by the Illinois Institute of Technology, and a Center for SEM Education at Contra Costa College.

Single investigator research programs make up a significant part of the ARO HBCU and MI program. Approximately $1 million is set aside for HBCUs and MIs in FY98 for research in several areas of interest to ARO. These areas include wireless communications, nonlinear optics, modeling and analysis of superplastic and electromagnetic materials, free electron lasers, and wide-bandgap semiconductors.

See Chapter VII–C.2 for additional information on support of HBCUs and MIs.

4. Single Investigator Programs

A major contributor to the Army science base is the single investigator working at a university and, to a lesser extent, in industry. These Army-sponsored researchers act as windows into the academic world for exploration of scientific discoveries. Individual investigators provide the Army with the ability to broadly impact the total science base, quickly exploiting opportunities that might arise. The research areas are relevant to Army needs and subject to scientific peer review. History has shown that the single investigator program has contributed significantly to the Army science base, with eight Nobel prizes awarded for Army-sponsored research. The areas of research pursued by the single investigator are discussed in the Surveys of Scientific Research (Section C) of this chapter.

5. Federated Laboratories

The AMC has a key research initiative to support the Army's thrust to digitize the battlefield. The objective of the Army digitization effort is to ensure the superiority of command and control (C^2) systems by providing warfighters with a horizontally and vertically integrated digital information network. This network will provide a simultaneous, consistent picture of the battlefield from soldier to commander at each echelon, as well as across all the services and allied forces. ARL has prime responsibility for the AMC's intramural research program and this program has been enhanced by the development of a federated laboratory concept.

The federated laboratory construct for conducting research is an innovative approach to integrating external research relevant to battlefield information systems—where the private sector has a substantial technology capability—with internal ARL research through the establishment of consortia in critical technology areas. Rather than developing or maintaining in-house research capabilities across the entire technologi-

cal spectrum, this approach leverages external expertise, facilities, and technologies in areas where the private sector has both the lead and the incentive to invest, such as in telecommunications technologies. To date, the Army is benefiting from $12.2 million in consortium investments, including $5.6 million to customize laboratories to support research defined in the *Annual Program Plan* and $5.9 million in independent research and development (IR&D) programs that have been redirected to support the research objectives of the federated laboratory. The intent of the federated laboratory is to form distributed public and private-sector teams that together conduct research, develop new technologies, and employ existing state-of-the-art concepts and infrastructure available in industry, academia, and the Army. This approach has produced an effective synergy between government, industry, and academia that will provide the maximum return on Army resources by:

- Adopting an integrated approach that combines the best of the public and private sectors to achieve future land warfare capabilities.
- Utilizing Army technical personnel in defining the *Annual Research Plan* to be executed with the consortia, ensuring it is focused on Army needs. The cooperative agreement managers (government leads) conduct quarterly reviews of the programs to ensure the focus is maintained and the consortia are executing their plans as scheduled. The federated laboratory also conducts program reviews with DDR&E Reliance Panels and Army R&D commands.
- Ensuring that the Army and DoD research communities are aware of the research being conducted by the federated laboratory. Each consortium conducted a symposium that drew a total of 720 people with over 1,200 copies of the symposia proceedings requested to date. In addition, in FY96 a total of 144 technical papers were published.
- Fostering and formalizing collaboration through the exchange of researchers from government to consortia and from consortia to government. This staff rotation is a foundation of the federated laboratory process and the target goal is to have twenty percent of the researchers on long-term rotation at any given time.
- Employing a unique management concept in which the government and the consortia, through a Consortium Management Committee, collaboratively develop and adjust research plans as formalized in the consortium' s *Articles of Collaboration.*
- Integrating the ARL federated research program with those at other Army and DoD components to ensure that there will be a smooth transition of research results, and that there is no duplication of effort.
- Fostering a technical management approach that ensures that the consortia programs are integral to the overall ARL program, and that creates an environment where academic, industry, and government researchers can identify and collectively address key Army technology gaps.
- Providing a way to adapt commercial technologies to the unique needs of the military environment, and allowing government research to impact the industry protocols and standards of the future.

In January 1996, the Army awarded three federated laboratory cooperative research agreements:

- Telecommunications/information distribution
  - Wireless communication
  - Tactical/strategic interoperability
  - Information distribution
  - Multimedia concepts

- Advanced and interactive displays
  - Soldier centered computer interface
  - Perception (sensory) based display formats
  - Cognitive measures of C^2 performance
- Advanced sensors
  - Multidomain smart sensors
  - Multisensor fusion
  - Radar
  - Signal processing
  - Microsensors.

The selection of research areas was based on the needs of the Army's Digitization Initiative and the priority of the research programs to meet critical technology gaps in the Force XXI and AAN visions. The consortia participants are listed in Table V–5. During the second year, the federated laboratory has attracted associate members and established no-cost collaborations with key sources of technology:

- Texas A&M University: Research perspectives on presentation and decision aids.
- Carnegie Mellon University: Modeling and simulation tools for information processing.
- Micovision: Virtual retinal display technology.
- MIL3, Inc.: Modify OPNET to better simulate military communications.

6. In-House Laboratory Independent Research

In-house laboratory independent research (ILIR) is a traditional part of the Army's basic research program. ILIR allocates 6.1 discretionary funds to the directors of selected Army research organizations to fund in-house research projects of exceptional scientific quality that have high risk but also very high potential payoff to the Army's science and technology programs. ILIR funds are distributed to Army RDECs, the Corps of Engineers, the Medical Research and Materiel Command laboratories, and ARI. ILIR is reviewed yearly by the Office of the Assistant

Table V–5. Federated Laboratory Consortia Participants

	Telecommunications/ Information Distribution	Advanced and Interactive Displays	Advanced Sensors
Industry Lead	Lockheed Sanders	Rockwell International	Lockheed Sanders
HBCU/MI Partners	Howard University Morgan State University	North Carolina A&T	Clark Atlanta University University of New Mexico
Academic and Industry Partners	Bell Communications Research City College of New York GTE Laboratories MIT Motorola University of Delaware University of Maryland	Microelectronics Center of NC Sytronics University of Illinois	Environmental Research Institute of Michigan Georgia Tech Research Institute Lockheed Missiles and Space Company MIT Ohio State University Research Foundation Stanford University Texas Instruments University of Maryland University of Michigan

Secretary of the Army (Research, Development and Acquisition) (OASA(RDA)), using metrics developed to assess programmatic effectiveness. The yearly review examines the quality, relevance, productivity, and resources of the ILIR work performed by each organization and determines its ratio of ILIR funding for the next fiscal year. This review results in only the best performers being rewarded. Within each organization, innovative research proposals submitted by scientists and engineers compete for ILIR funding through internal management and technical reviews of the proposals.

Successful ILIR projects, on completion, will typically define a start-up project for 6.1 or 6.2 mission funding within the organization. In addition to providing a pathway for the development of novel and high quality research projects by providing support for the most innovative and often speculative ideas, this program is instrumental in enhancing the recruitment and retention of outstanding scientists and engineers. The creative atmosphere fostered in this manner is essential to the identification of emerging operational concepts and technology thrusts for the future.

7. *Army After Next* Research Areas of Emphasis

The *Army After Next* project conducts broad studies of warfare to frame issues vital to the development of the U.S. Army to about the year 2025, and provides these issues to the senior Army leadership in a format suitable for integration into Training and Doctrine Command's (TRADOC) combat development programs. The AAN project conducts its studies through an annual cycle of wargames and workshops that culminates in an annual report to the Army Chief of Staff. Studies are currently pursued in four areas focused out to 2025: *geopolitics, military art, human and organizational behavior,* and *technology.* Those studies focused on *technology* are of prime importance to the Army's research effort.

The first year of study by the AAN project resulted in recommendations for investments in basic research that were assessed to have the greatest potential in producing key enabling technologies for the U.S. Army in the 2010–2025 timeframe. OASA (RDA) has taken these recommendations and developed an approach to focus basic research investments based on defense SROs by:

- Emphasizing specific aspects of current defense SROs.
- Developing a set of emerging Army SROs.
- Studying those areas of emphasis highlighted by the AAN project for other emerging SROs.

Note: Army efforts toward defense SROs are discussed in Section B.8 of this chapter.

Defense SROs support emerging AAN technology needs as follows:

Defense SRO	AAN Emphasis for Research
Mobile Wireless Communications	Expand to include terrain- and environment-independent communications and data management
Biomimetics	Address lightweight protective materials
Intelligent Systems	Address unmanned vehicles and robotics concepts

The Army leadership is discussing the possibility of identifying specific Army SROs in addition to defense SROs, that support the AAN. For FY98 the basic research budget dedicated to SRO topics is expected to increase from the current 15 percent to approximately 30 percent. Leading candidates for possible Army SROs emerging from AAN studies are:

- Enhanced soldier combat performance
  - Physiological enhancements (nutrition/medical interventions)
  - Cognitive engineering
- Signature management/control
- Full-dimensional protection for information systems

- Microminiature multifunctional sensors

The AAN project also recognizes that basic research may provide unexpected and revolutionary technologies that can further enhance the capabilities of future Army forces or, in extreme cases, fundamentally impact the system, design, and operational concepts upon which these forces will be based. While seeking major breakthroughs in technology, the synergy among currently developing research and technologies must be exploited to achieve revolutionary effects for the AAN forces. Some technology areas that have been identified as potentially enabling for the AAN force are:

- Hybrid power systems
- Fuel efficiency (reduce consumption by 75 percent)
- Human engineering/cognitive engineering
- Signature control (including counters)
- Protection schemes for land systems (including active protection)
- Advanced materials
- Alternative propellants
- Chemical and biological (CB) protection, antidotes, and vaccines
- Logistics efficiencies.

The AAN has identified systems to provide perspective to the basic research community in imagining where basic-research-derived technologies may be applied in 2010–2025. They include:

- Future ground craft
- Advanced airframe, including heavy lift/tactical utility lift
- Autonomous and semiautonomous unmanned systems (air, ground, sensors)
- Advanced fire support system
- "Living internet"
- Active protection
- Soldier as a system.

The Army will leverage and support to the maximum requirements from the other services, academia, and commercial industry that support AAN capabilities. The Army will direct its basic research dollars toward those Army-unique technologies that are critical to AAN force capabilities. Examples of other service activities that have great potential for leveraging are:

- Navy: Fast sealift—speeds in excess of 50 knots
- Air Force:
  - Larger cargo lifter—1 million pound lift capacity
  - Unmanned aerial vehicles (UAVs)
- Marine Corps: Nonlethal technologies.

8. DoD Strategic Research Objectives

In coordination with other DoD departments and agencies, the U.S. Army has defined six SROs that synergistically focus multidisciplinary research themes to achieve technology enablement in 10–15 years, with a high potential payoff in numerous Army applications. These SROs were originally envisioned to encompass about 15 percent of the Army 6.1 research budget. Accordingly, the Army has identified approximately this percentage of its 6.1 research program with the six currently approved DoD-wide SROs: biomimetics, nanoscience, smart structures, mobile wireless communications, intelligent systems, and compact power sources. The Army is currently expanding these DoD SROs to facilitate the recognition of Army-specific research themes in areas such as information dominance, enhanced soldier performance, tunable lethality, protection of information systems, advanced compact and multifunctional sensors, and science for innovations in logistics. A more detailed description of the current six SROs follows.

a. Biomimetics

Objective

As an SRO, biomimetics aims to enable development of new structural and functional materials and technologically innovative approaches toward sensing and information processing, with product and process lessons from nature contributing to design principles, performance capabilities, and manufacturing possibilities.

Approach

To accomplish this goal, biomimetics seeks to benefit from the direct manipulation of a process of biological origin or from engineered exploitation that derives a product or process design or function from a naturally occurring system. The overall approach is one that incorporates in a wholly integrated manner the most advanced and diverse conceptual and experimental tools of a number of scientific disciplines, including, but not limited to, biology, materials science, chemistry, physics, math and computer sciences, and electronics. There are numerous materials occurring in biological systems that exhibit remarkable properties. Uniquely, these materials derive their functionality from fabrication processes composed of several levels of self-assembly involving molecular clusters organized into structures of different length scales. Some of these materials are able to effect exceptionally efficient transfer of mass, charge and energy over a very wide range of performance durations, or to provide unique supportive and protective structures. Biological systems also have exquisite and highly integrated sensing capabilities that allow rapid and selective recognition and signal processing that can detect and classify target molecules, men, or machines in noisy and cluttered environments. Sensors designed using biological principles offer the possibility of novel classes of sensors, far more sensitive and rapid than anything available today.

Military Potential

Rapidly emerging advances in this very young area of scientific endeavor show substantial promise to affect a number of Army applications. Contributions are expected to cover a wide range, including tough, lightweight composites for armor, chemical detection applicable to explosives and nerve agents, novel fibers for individual soldier protection, and catalysts for both synthetic and degradative purposes. Potential Army applications are noted in Figure V–1.

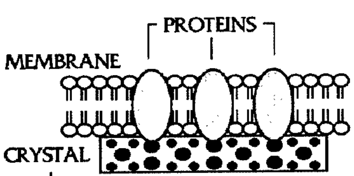
Lessons From Nature	*Mimic Nature—Biomimetics*	*New Advanced Materials*	*Army Systems*
Seashell Formation by Crystalization	• Micro-Layer Polymers • Synthetic Nacre	• Food Wrap • Armor • Smart Films • Wear Resistant	SOLDIER • Armor • Helmet • Goggles • Power • CBN • Food
	• Nano Mineralization	• Chemical Detection • High Energy Density Storage	STRUCTURAL • Vibration • Armor • Insulation • Wear
	• Synthetic Macro-Molecules	• Quantum Well Films • Non-Linear Optics • Nano-Magnetics	FUNCTIONAL • Power • Displays • MEMs • Memory
• $CaCo_3$ • SiO_2 • $BaTiO_3$ • Fe_3O_4	• Transduction Elements	• pH Control • $ Savings • User Friendly	SOCIAL/ECONOMIC • Drugs • $ Savings • Explosives • Bio-friendly

Figure V–1. Biomimetics Research Explodes in Applications for *Army After Next*

b. Nanoscience

Objective

Achieve dramatic, innovative enhancements in the properties and performance of structures, materials, and devices that have controllable features on the nanometer scale (i.e., tens of angstroms).

Approach

Army support for nanoscience research is focused on creating new theoretical and experimental results involving atomic scale imaging methods, subangstrom measurement techniques, and fabrication methods with atomic control that will provide reproducible material structures and novel devices. It also includes direct investigations of phenomenological evolution that is dominated by size effects or quantum effects. These quantum effects may, in turn, be used as the basis for fundamentally new capabilities or for enhancing the performance of existing devices. Similar control over the electromagnetic propagation in nanostructured materials may allow for more precise control of microwave, infrared, and visible radiation. Scientific opportunities include understanding new phenomena in low dimensional structures, nucleation and growth, self-organizing materials, site-specific reactions, and three-dimensional (3D) nanostructural materials.

Military Potential

The ability to fabricate structures affordably at the nanometer scale (as illustrated in Figure V–2) will enable new approaches and processes for manufacturing novel, more reliable, lower cost, higher performance, and more flexible electronic, magnetic, optical, and mechanical devices. Recognized applications of nanoscience include ultra small, highly parallel and fast computers with terabit nonvolatile random access memory and teraflop speed, image information processors, low power personal communication devices, high-density information storage devices, lasers and detectors for weapons and countermeasures, optical (IR, visible, ultraviolet (UV)) sensors for improved surveillance and targeting, integrated sensor suites for CB agent detection, catalysts for enhancing and controlling energetic reactions and decontamination, synthesis of new compounds (e.g., narrow-bandgap materials and nonlinear optical materials) for advanced electronic, magnetic, and optical sensors, quantum computation for code breaking, resource optimization and wargaming, photonic band engineering for sensor protection, powerful radar, and low observables, and significant life-cycle cost reductions in many systems through failure remediation. These devices exploit exciting properties of nanoscale materials not predictable from macroscopic physical and chemical principles.

c. Smart Structures

Objective

Demonstrate advanced capabilities for modeling, predicting, controlling, and optimizing the dynamic response of complex, multielement, deformable structures used in civil structures, land vehicle, weapon, and rotorcraft systems.

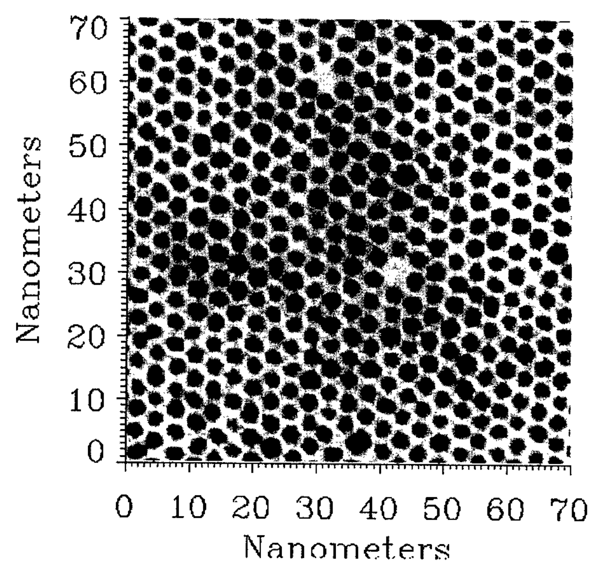


Figure V–2. Nanometer-Scale Micrograph. A transmission electron micrograph of ~3 nm diameter gold clusters encapsulated by dodecanethiol that self-assembled into this array when deposited on a thin flake of molybdenum disulfie.

Approach

Smart structures offer significant potential for expanding the effective operations envelope and improving certain critical operational characteristics for many Army systems. Key characteristics of smart structures include embedded or bonded sensors and actuators linked to a controller responsive to external stimuli to compensate in real time or quasi-real time for undesirable effects or to enhance overall system performance. To help realize the full potential of smart structures in military systems, the Army's basic research program is supporting fundamental investigations that address active/passive structural damping techniques, advanced actuator concepts able to provide greater forces and displacements, embeddable and nonintrusive sensors, and smart actuator materials (e.g., piezoelectric, electrostrictive, and magnetostrictive materials, shape memory alloys, magnetorheological fluids). Important studies focused on new fabrication processes for actuators and sensors on the micron to millimeter scale, computationally accurate and efficient constitutive models for smart materials, advanced mathematical models for nonconservative and nonlinear structural and actuator response, robust hierarchical control with distributed sensors and actuators, and concurrent, integrated structural design and control methodologies are also being pursued.

Military Potential

Specific potential military applications of smart structures include shock isolation and machinery vibration, vibration control and stability augmentation systems in rotary wing aircraft to extend structural fatigue life and reliability, barrier structures providing improved protection against CB agents, structural damage detection and health monitoring systems, more accurate rapid fire weapon systems, fire control and battle damage identification, assessment, and control of active, conformal, load-bearing antenna structures, phased arrays, and broadband spiral antenna systems (see Figure V–3).

d. Mobile Wireless Communications

Objective

Provide fundamental advances enabling the rapid and survivable communication on-the-move (OTM) of large quantities of multimedia information (speech, data, graphics, and video) from point to point, broadcast, and multicast over distributed mobile wireless networks for heterogeneous command, control, communications, and intelligence (C^3I) systems.

Approach

Research on high frequency devices, sources, and waveguides and techniques such as quasi-optical power combining can increase radio carrier frequencies beyond 20 gigahertz (GHz) where channels can have wider bandwidths and consequently greater capacity. Research on processing for smart antennas with beamsteering, diversity combining, and spectrum reuse and new methods of source, channel, and modulation coding enable increased capacity with lower power, extending battery lifetime and reducing probability of interception. Protocol engineering research provides the technology to integrate cable, satellite, and mobile wireless heterogeneous networks and to maintain connectivity, routing, and quality of service for multimedia communications in highly dynamic battlefield conditions. Modeling and simulation (M&S) research is performed to assess performance and network stability and to evaluate propagation phenomena in urban and rural environments.

Military Potential

Research in this area provides the technology for establishing and maintaining mobile wireless network communications OTM under the harsh and highly dynamic conditions of modern battlefields. Civil networks have a fixed structural component (e.g., cellular towers) not usable in mobile military systems and the military channel is more complex and dynamic. Timely arrival of messages is highly critical to military operations and networks can have no single points of failure and must be self-organizing to be survivable.

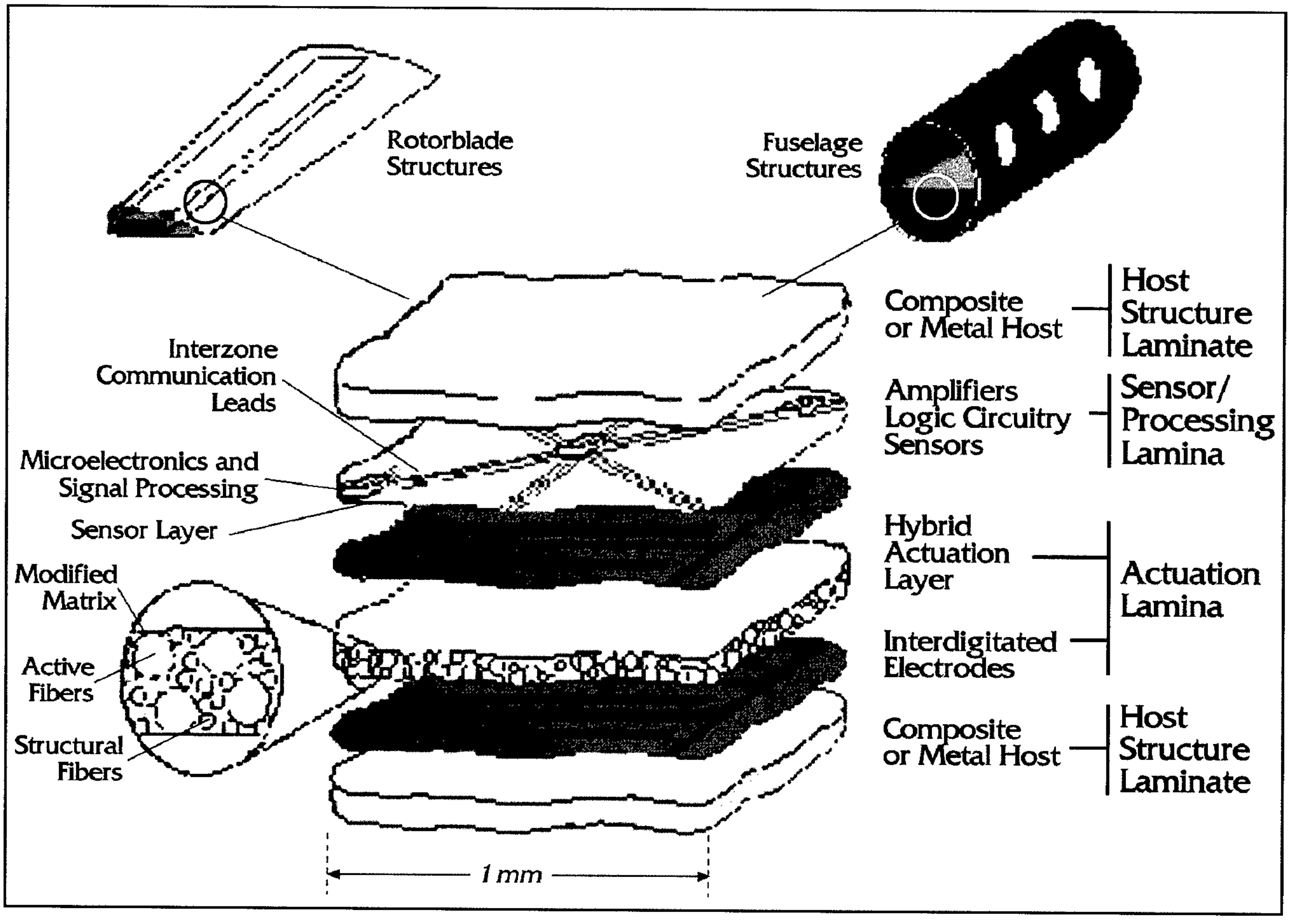


Figure V–3. Smart Composite Actuator Concept and Army Applications

Research in mobile wireless communications is needed to dramatically improve the throughput, survivability, and security of complex mobile wireless networks critical to the success of future Force XXI and AAN highly mobile operations. Advances in mobile wireless communications will significantly increase the capacity, reliability, and survivability of the Army's battlefield information distribution systems (see Figure V–4).

e. Intelligent Systems

Objective

Enable the development of advanced systems able to sense, analyze, learn, adapt, and function effectively in changing or hostile environments until completing assigned missions or functions.

Approach

Intelligent systems offer exciting new possibilities for conducting many types of military operations, ranging from reconnaissance and surveillance activities to a variety of specialized combat operations. Intelligent systems typically consist of a dynamic network of agents interconnected via spatial and communications links that operate in uncertain and dynamically changing environments using decentralized or distributed input and under localized goals that may change over time. The agents may be people, information sources, or automated systems such as

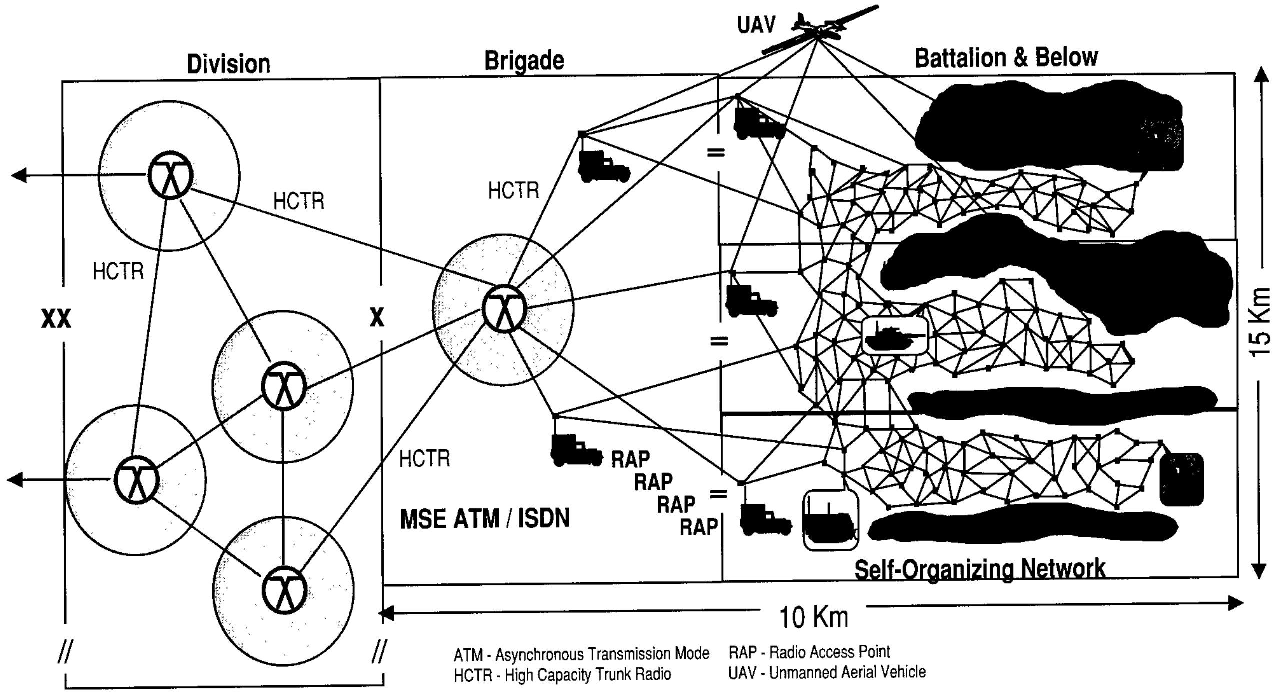


Figure V–4. Mobile Wireless Communications. Seamless mobile wireless communication is the underpinning of many of the capabilities for the *Army After Next* and the *Joint Warfighting Science and Technology Plan.* In the 21st century, DoD must field a robust mobile wireless communication system that can provide communications OTM to warfighters, integrate heterogeneous network protocols, including commercial protocols such as ATM, integrated services digital network (ISDN), and transmission control protocol/Internet protocol (TCP/IP), and multimedia (video, voice, and data) services. This SRO addresses these issues for spatial reuse of channels, robust compression for wireless channels, and operation with minimum energy to extend battery lifetime.

robots, software, and computing modules (see Figure V–5).

Military Potential

Intelligent systems must be capable of gathering relevant, available information about their environment, analyzing its significance in terms of assigned missions/functions, and defining the most appropriate course of action consistent with programmed decision logic. Achieving these objectives requires integration of significant scientific and technological advances in many diverse fields: electronics, physics, mathematics, materials science, biology, computer science, cognitive and neural sciences, control theory and mechanisms, and electrical and systems engineering. Critical areas of research being pursued include the design of multiagent systems, representation of hierarchical perception systems, advanced models for learning and adaptation, development of effective frameworks for representing and reasoning with uncertainty, and new computational paradigms for accommodating imprecision in human centered systems. The numerous potential military applications of intelligent systems include unmanned vehicles (air and ground), smart weapons, real-time C^2 systems for future battlefields, and CB defense systems.

f. Compact Power Sources

Objective

Identify and exploit new concepts in portable power, especially in fueled systems, to increase the energy density and lower the cost of subkilowatt power sources.

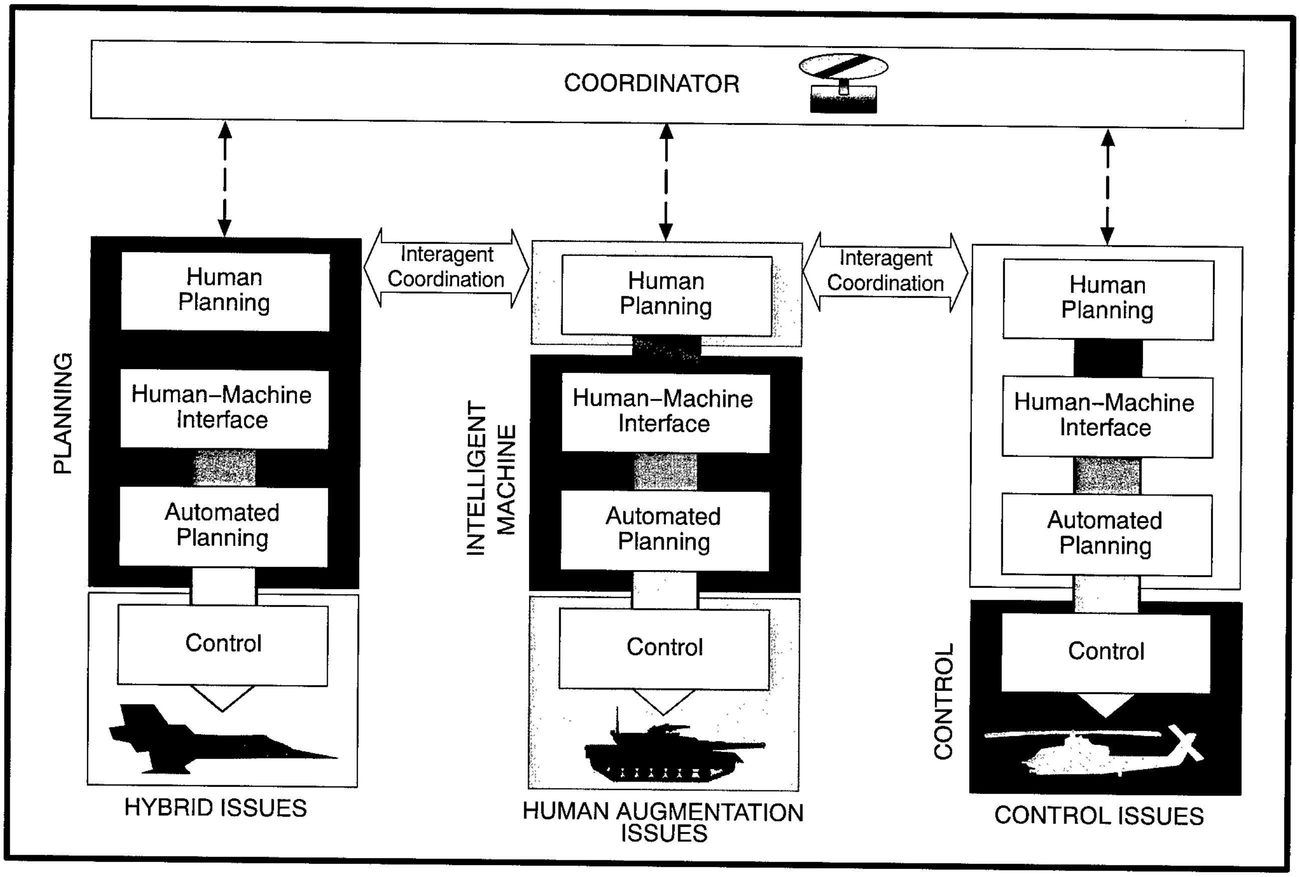


Figure V–5. Intelligent Digital Battlefield Architecture. Intelligent systems research includes activities pertinent to the performance of hybrid systems, human intelligence augmentation, and low-level control. Hybrid system research will lead to robust design of advanced architecture for multiagent/distributed control. Research involving representation and learning in the presence of uncertain or incomplete information (soft computer: neural networks, fuzzy logic, Bayesian decision theory, etc.) will provide tools for intelligence augmentation of human-centered decision systems.

Approach

The energy density of typical fuels exceeds that of batteries by 10–100 times. Lightweight energy converters, using air as the oxidizer, are the key to exploiting the high energy content of such fuels. Converter technologies under study include fuel cells, microturbines, thermophotovoltaic systems, and alkali metal thermal-to-electric converters.

Military Potential

Small, lightweight energy converters may be used in a variety of configurations. Hydrogen/air fuel cells can now be made small enough (50-watt fuel cell stack is a cube 6 centimeters (cm) on a side, see Figure V–6) to be put into battery cases and used as long-lived, refuelable, direct replacements for batteries. Microturbines hold the promise of providing up to 20 times the energy storage of a battery system of similar weight. Alternatively, for applications requiring air-independent operation, it may be desirable to use the small converters as lightweight, portable battery chargers. Many applications may be best supported with hybrid systems consisting of high discharge rate, low energy density, rechargeable batteries that can provide high peak powers and that are kept recharged by small (a few watts) fueled battery chargers running at low power on a nearly continuous basis. The hybrid systems should be able to provide the ease of distribution of battery power combined with the

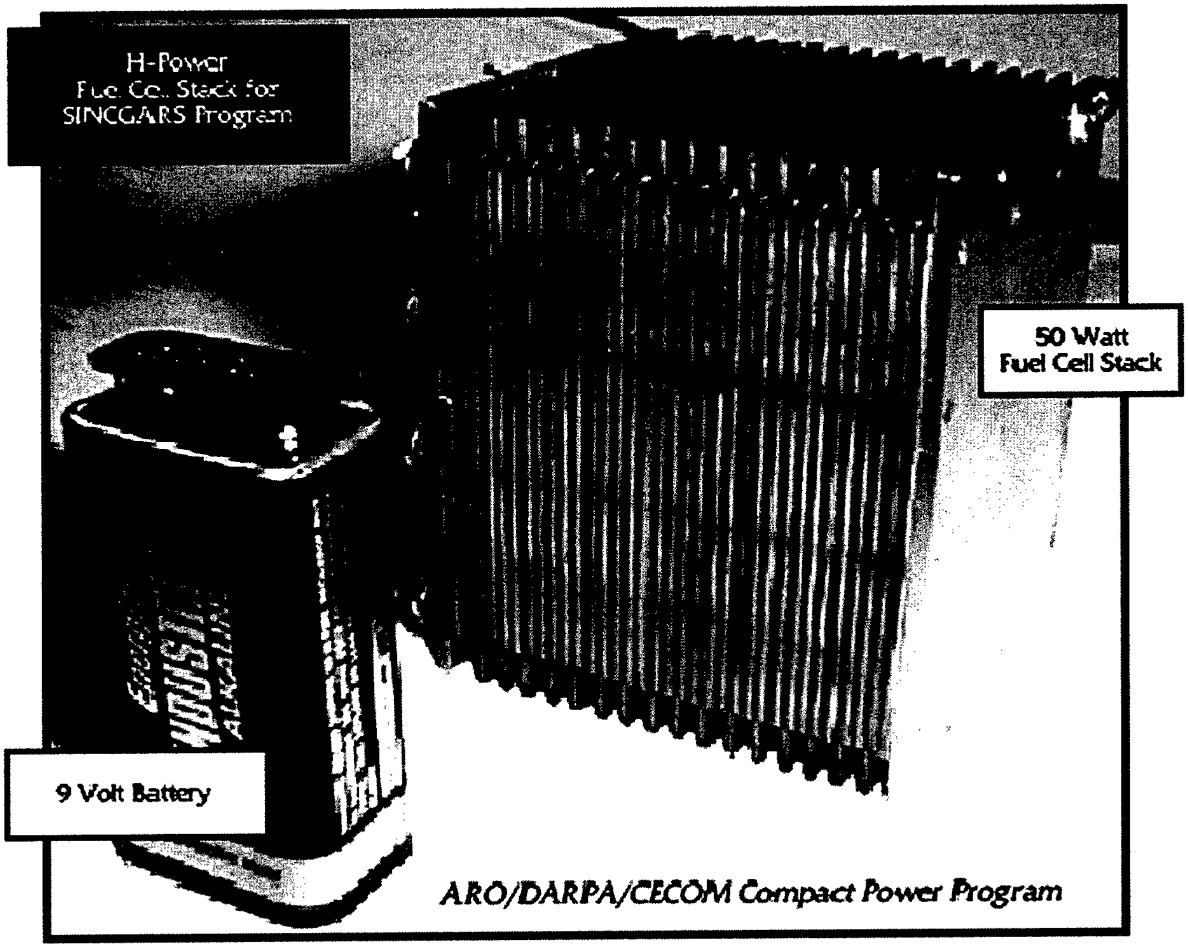


Figure V–6. Compact Power Sources

high energy density of fuels in long-lived systems with low life-cycle costs.

Strategic Research Objective Goals

In managing the Army's basic research program, special attention is being given to these SROs to help ensure that their potential can be realized through subsequent technology and system development efforts. Identification of additional areas and objectives will be sought in continuing reviews of basic research activities. Representative specific research goals associated with the SROs described above are provided in Table V–6.

9. Other Academic Leveraging

During times of seriously diminishing budgets, increased leveraging becomes more desirable and necessary to help mitigate the impact of funding cutbacks on R&D programs. In addition to the preceding academic programs, the Army is significantly leveraging several other major academic institutions and consortia.

The Center for Advanced Food Technology (CAFT) at Rutgers University is funded by industrial member fees, State of New Jersey funding, Rutgers University funding, and government grants. The Army's basic membership fee is leveraged by a factor of 60 in relation to the overall CAFT operating budget. Members, including the Natick Research, Development and Engineering Center (NRDEC), have an active role in selecting research projects for funding and monitoring their progress. Research reports are provided to members and active collaboration with CAFT investigators is ongoing for NRDEC. CAFT work complements in-house Army R&D.

Table V–6. Representative Specific Army Basic Research Goals Associated with DoD Strategic Research Objectives

2005	2010 Army XXI	2025 *Army After Next*
Biomimetics		
Characterize enzymatic breakdown of chemical threat agents at molecular level Define role of biomolecular recognition based interactions in superstructure formation Novel optical processing materials	Foundation for mimicking active site mechanism of catalysis Predictive rules and methods for biomimetic hierarchical nanomaterials fabrication	Robust biomimetic catalytic system developed for chemical agent decontamination Manipulation of macromolecular properties to achieve optimal performance Novel process for ceramic composite manufacture
Nanoscience		
Efficient microwave radar Broadband optical limiting High bandwidth communication	Hybrid CB sensors IR low observables Terabit, teraflop computers	Rapid CB decontamination Atom interferometer gyroscope Quantum computing
Smart Structures		
Demonstrate up to 60-decibel (dB) vibration reduction using shaped actuators and adaptive control algorithms Achieve MEMS wireless communications in a rotorcraft flight structure Demonstrate new impact energy absorbing active materials	Demonstrate a low-cost, self-tuning structural vibration damping treatment with integrated power sources and signal processing capability Demonstrate addressable optical fiber sensor arrays to measure temperature and strain for damage detection in composite structures Achieve high force/high displacement actuators fabricated from improved active materials	Demonstrate smart, conformal, load bearing multifunctional antenna structures for rotorcraft and land vehicles Realize active material based rotor blade control for stealthy, long-range, and highly maneuverable rotorcraft Achieve high precision controlled pointing and tracking techniques for accurate weapon systems for rotorcraft and land vehicles
Mobile Wireless Communications		
Communicate OTM networks Multimedia services over wireless networks Aerial relay to maintain connectivity High RF power efficient systems design	Conformal antennas for vehicles Multifunction antennas for communications Video for mobile wireless networks Seamless, ubiquitous communications	Adaptive, self-organizing networks Living internet Smart antennas for portable transceivers Extremely low probability of intercept signals Personal communication devices
Intelligent Systems (IS)		
Establish fundamental roles played by hierarchical organization, compositionality, and learning in IS design Define/characterize simulated battlefield environments for testing IS methodologies Demonstrate intelligence augmentation of human centered systems, with emphasis on cognitive issues	Establish a framework for integrating high and low level aspects of intelligent systems Exploit framework in devising next-generation control algorithms and designing prototype systems (e.g., that have integrated vision/control systems) Define/characterize integration of intelligent systems into larger network of systems (e.g., C^3I)	Achieve new understanding of learning styles in the human brain relevant to the design of intelligent systems Demonstrate useful performance characteristics of fully autonomous intelligent systems Demonstrate advanced sensor/control capabilities of fully autonomous intelligent systems

Table V–6. Representative Specific Army Basic Research Goals Associated with DoD Strategic Research Objectives (continued)

2005	2010 Army XXI	2025 *Army After Next*
Compact Power Sources		
Demonstrate compact direct methanol fuel cells via low crossover membranes and methanol tolerant catalysts (performance = hydrogen) Demonstrate liquid-fueled microturbine generator with efficient power electronics (>10 W/ cm^3) Demonstrate quiet liquid-fueled thermophotovoltaic power sources (250 W/kg)	Demonstrate 300-W compact fuel cell that operates on logistics fuels at moderate temperatures Demo liquid-fueled microturbine generator with efficient power electronics (>100 W/ cm^3) Demo high efficiency (>25%) logistic fueled alkali metal thermal-electric converter (AMTEC) power system	Low-cost, highly reliable fielded power systems made possible by better materials design and improved manufacturing processes Use biotechnology to produce useful quantities of fuel from renewable resources

The Oregon State University Consortium for High Pressure Food Preservation is another example of the Army's receiving a greater return on a relatively small investment. Similarly, the Ohio State University Center for Non-Thermal Processing is being leveraged in its effort to move pulse electric field processing to commercialization, which will benefit the Army as well as the private sector.

The Army also participates in the University of Massachusetts (Amherst) Center for Research in Polymers, where new polymers and polymeric materials are explored. NRDEC has recently initiated a student research experience program with the University of Massachusetts at Dartmouth (UMD), whereby students from the Textile Science Department will work on Army projects for college credit. This program is expected to expand to other UMD departments. UMD is being further leveraged due to its recent research involvement with the National Textile Center.

The airdrop program at NRDEC has been leveraged by work at the Universities of Minnesota and Connecticut and more recently at the South Dakota Bureau of Mines and Technology and Parks College of Saint Louis University. These efforts are focused on airdrop system modeling and computer designs of complex fluid structure interactions and have minimized the need to build and test multiple prototypes. Teaming with experienced universities has significantly reduced the time required to achieve desired goals.

NRDEC and ARL hold a joint membership in the Northeastern University Center for Electromagnetics Research, which conducts research in the area of electromagnetic waves and their interactions with materials. As a voting member of the center, NRDEC can impact the direction of ongoing and future research efforts to support the needs of the Army, which benefits significantly from this leveraging.

The effective leveraging of quality academic institutions, centers, and programs has greatly assisted numerous significant Army efforts, which are experiencing resource reductions.

C. EXECUTION—SCIENTIFIC RESEARCH AREAS

The Army has established a vigorous research program covering a wide range of disciplines to capture and exploit the new opportunities presented by research advances and discoveries. This program is executed primarily by university contractors and in-house laboratory and RDEC personnel, and maximizes the use of the initiatives noted in Section V–B above.

Within a wide spectrum of research, several primary areas emerge that are of particular importance to tomorrow's Army. These efforts in the following research areas are described in the sections that follow:

1. Mathematical sciences
2. Computer and informational sciences
3. Physics
4. Chemistry
5. Materials science
6. Electronics research
7. Mechanical sciences
8. Atmospheric sciences
9. Terrestrial sciences
10. Medical sciences
11. Biological sciences
12. Behavioral, cognitive, and neural sciences.

1. Mathematical Sciences

a. Strategy

Mathematics plays an essential role in modeling, analysis, and control of complex phenomena and systems of critical interest to the Army. Mathematical modeling is increasingly being identified as critical for progress in many areas of Army interest. The mathematical and scientific tasks in these areas of interest are frequently of significant complexity. As a result, researchers from two or more areas of mathematics must often collaborate together and with experts from other areas of science and engineering to achieve Army goals. Some examples of cross-cutting areas of research include the breakup of liquid droplets in high-speed air flow (for determination of the dispersion of chemical or biological agents spilled from intercepted theater-range missiles), computational methods for penetration mechanics, and automatic target recognition. For example, promising approaches to computer vision for automatic target recognition require research in a wide range of areas including constructive geometry, numerical methods, stochastic analysis, Bayesian statistics, probabilistic algorithms, and distributed parallel computing. To achieve Army goals, research in several areas is important:

- Applied analysis
- Computational mathematics
- Probability and statistics
- Systems and control
- Discrete mathematics.

An investment strategy meeting with participants from ARO, ARL, RDECs, Corps of Engineer Waterways Experiment Station (WES), Concepts Analysis Agency (CAA), Deputy Under Secretary of the Army (Operations Research) (DUSA(OR)), and academia identified several exciting research areas that will have significant impact on future Army technologies. Based on these recommendations, research priorities inside these areas are listed below.

b. Major Research Areas

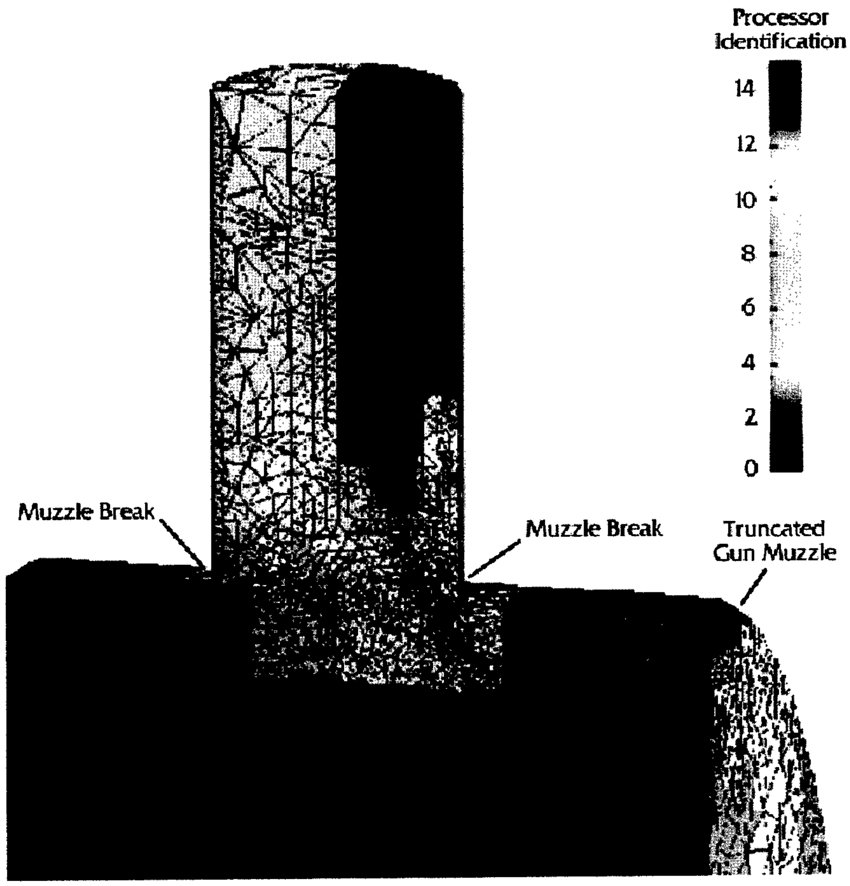
Applied Analysis

Physical modeling and mathematical analysis for nonlinear ordinary and partial differential, difference, and integral equations for:

- Advanced materials, including smart materials and structure and advanced composites.
- Fluid flow, including flow around rotors, missiles, and parachutes, combustion, detonation and explosion, two-phase flow, and granular flow.
- Nonlinear dynamics for optics, dielectrics, electromechanics, and other nonlinear systems, and physics-based mathematical models of human dynamics.

Computational Mathematics

- Rigorous numerical methods for fluid dynamics, solid mechanics, material behavior, and simulation of large mechanical systems (see Figure V–7).
- Optimization: large-scale integer programming, mixed-integer programming, and nonlinear optimization.



The differently shadedregions are solved on different processors of a parallel computer system.

Figure V–7. Modeling the Fluid Flow Within the Muzzle Break of a Gun

Probability and Statistics

- Stochastic analysis and applied probability: stochastic differential equations and processes, interacting particle systems, probabilistic algorithms, stochastic control, large deviations, simulation methodology, and image analysis.
- Statistics: analysis for very large data sets or very small amounts of data from nonstandard distributions, point processes, Bayesian methods, integration of statistical procedures with scientific and engineering information, Markov random fields, and cluster analysis.

Systems and Control

- Mathematical system theory and control theory: control in the presence of uncertainties, robust and adaptive control for multivariable and nonlinear systems, system identification and its relation to adaptive control, hybrid control, hybrid-infinity control, and nonholonomic control.
- Foundations of intelligent control systems: discrete event dynamical systems, hybrid systems, learning and adaptation, distributed communication and control, and intelligent control systems.

Discrete Mathematics

- Computational geometry, logic, network flows, graph theory, and combinatorics.
- Symbolic methods: computational algebraic geometry for polynomial systems, discrete methods for combinatorial optimization, symbolic methods for differential equations, mixed symbolic-numerical methods, parallel symbolic sparse matrix methods, and algorithmic methods in symbolic mathematics.

c. Potential Military Benefits

With the change from a predictable large threat to numerous and often unpredictable regional threats, the need for more flexibility in Army systems and more rapid development of these systems increases. As the cost of physical experimentation increases, the role of mathematical modeling becomes more important. Mathematical modeling is a major factor in ensuring that a system is well designed and that it will work once built. In all of the following areas, mathematics is a fundamental tool required by the Army of the present and the future:

- Design of advanced materials and novel manufacturing processes.
- Behavior of materials under high loads, failure mechanics.
- Structures, including flexible and adaptable structures.
- Fluid flow, including reactive flow.
- Power and directed energy.
- Microelectronics and photonics.
- Sensors.
- Automatic target recognition.
- Soldier and aggregates of soldiers as systems: behavioral modeling, performance, mobility, hear-stress reduction, camouflage (visible, IR), chemical and ballistic protection.

2. Computer and Information Sciences

a. Strategy

The computer and information sciences address fundamental issues in understanding, formalizing, acquiring, representing, manipulating, and using information. The advanced systems, including the software engineering environments and new computational architectures facilitated by this research will often be interactive, adaptive, sometimes distributed and/or autonomous, and frequently characterized as intelligent. Computer-based systems that process information and transfer data and analysis among various Army commanders and units are essential for military success.

The computer science and software issues that arise in this context often require input from a number of subdisciplines of computer science, as well as from other disciplines. Multisensor fusion, multi-image fusion, image understanding, language processing, distributed interactive simulation, multivariable and multiresolution methods for terrain modeling, scalable parallel algorithms and algorithms for processing large-scale data are but a few of these areas. In these areas, computer and information sciences research is organized in a cross-cutting fashion to provide the expertise needed to accomplish the Army goal (rather than remain within traditional disciplinary boundaries). Based on the recommendations from an investment strategy meeting among senior scientists from ARO, ARL, RDECs, TRADOC, DUSA(OR), CAA, COE, and academia, research in the following areas was determined to be important to the Army:

- Theoretical computer science
- Formal methods for software engineering
- Software prototyping, development, and evolution
- Knowledge base/database systems
- Natural language processing
- Intelligent systems.

b. Major Research Areas

Theoretical Computer Science

- Formal models underlying computing technology, optimization of input/output (I/O) communication, new computing architectures, multiprocessing, parallel systems, and advanced architectures.
- Graph theoretic methods applied to parallel and distributed computation, models, and algorithms for the control of heterogeneous concurrent computing.

Formal Methods for Software Engineering

- Software engineering architectures: environments, tools, integrated tool sets.
- Graphical interfaces: multilevel displays for requirements elicitation, simulation, logic visualization.
- Software generation: invocation of formal methods, software reuse.
- Software evolution: change, merging, documentation.
- Software reliability: validation, verification.

Knowledge Base/Database Sciences

- Heterogeneous data structures: mediators, complex reasoning.
- Machine learning: methodologies for uncertainty, incompleteness, information recognition and content-based retrieval.
- Multimodal information: synthesis of knowledge from multimodal resources.
- Query/interrogation languages: domain-specific languages.

Natural Language Processing

- Text: content-based retrieval and understanding.
- Speech: translation, understanding, and generation with dialogue.

c. Potential Military Benefits

The contributions of the computer and information sciences to a well-equipped strategic force capable of decisive victory in conflicts in the Information Age are important in the following areas:

- Digitized battlefield
- Distributed C^2
- Information processing
- Distributed interactive simulation (DIS) (see Figure V–8)
- Design and validation of software and of large software systems
- Adaptive, anticipative systems
- Intelligent systems
- Human/machine interface
- Intelligence augmentation of human-centered systems
- Battlefield management.

3. Physics

a. Strategy

Physics provides the fundamental underpinnings for all other sciences and technologies. For this reason, emphasis is placed upon establishment of limits of technologies. A strategy for investment is developed by the Physics Coordinating Group with representatives from participating RDECs, ARO, ARL directorates, and the Topographic Engineering Center. This group has developed a 3-year plan for a broad-based research program that is organized into five subject areas:

- Nanoscience
- Photonics
- Integrated sensory science
- Nonlinear optics
- Image analysis.

These programs support advanced technology development to provide increased signal processing and display, sensor protection and countermeasures, and target acquisition.

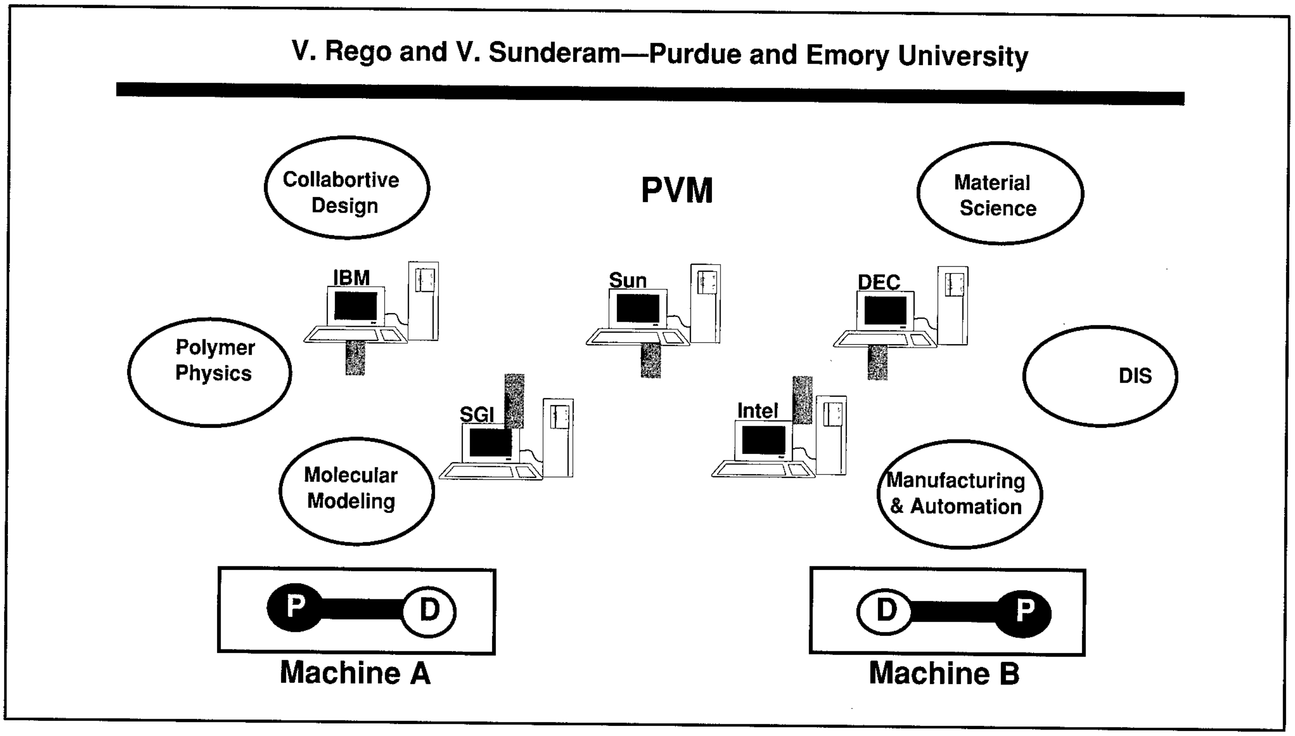


Figure V–8. High-Performance Concurrent Simulations. High-performance concurrent simulation provides enabling technology and prototype framework for seamless, portable, secure, scalable, and fault-tolerant concurrent computing on heterogeneous networked computers for collaborative applications.

b. Major Research Areas

Nanotechnology

The objective of nanotechnology is to develop the capability to manipulate atoms and molecules individually, to assemble small numbers of them into nanometer size devices, and to exploit the unique physical mechanisms that operate in these devices. The program emphasizes self assembly for the rapid, low-cost construction of these nanosystems.

Electrochemical polishing is a recently discovered technique for the production of quasi-periodic quantum dot arrays. Figure V–9 shows an aluminum film that has been electropolished to produce a dot pattern with a period of 100 nm and a peak to valley height of 50 nm. Other areas of emphasis in this program are ultra fast phenomena, near-field microscopy, nanoscale manipulation, photonic band engineering, quantum processes for noise reduction, and new radiation sources.

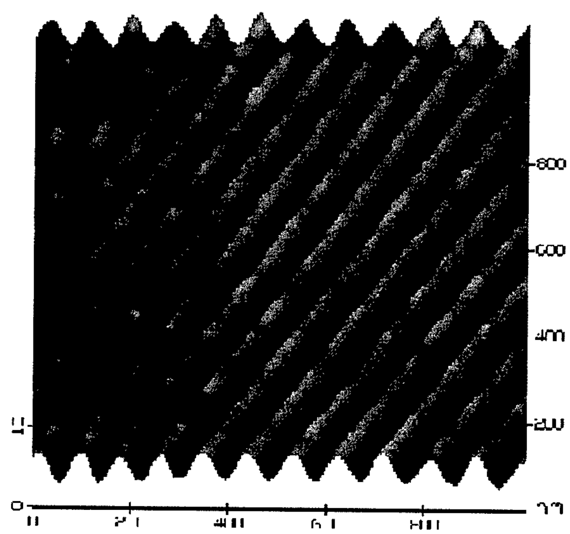


Figure V–9. Magnified Atomic Force Micrograph. An "egg-carton" pattern on the surface of an electropolished aluminum surface. The pattern was produced after polishing for 30 seconds using techniques routinely used by the anodizing industry.

Photonics

Photonics seeks to develop optical subsystems for military applications such as information storage, displays, optical switching, signal processing, and optical interconnections of microelectronic systems. Research opportunities exist in diffractive optics, hybrid signal processing, and unconventional imaging.

Integrated Sensory Science

Integrated sensory science seeks to provide the Army the ability to operate on the ground over relatively short ranges in conditions of poor visibility. Novel and improved radiation sources and detectors will continue to provide new capabilities for the Army, especially with the utilization of coherent optical and atomic systems and of multispectral imaging. Control of physical signatures is now within our capability with the discovery of new materials and of enhanced backscattering.

Nonlinear Optics

The use of optical sensors and sources is analogous to the use of radio frequency detectors and sources. In the future, optical warfare should become as important as electronic warfare. Nonlinear optical processes, tunable sources, materials with special reflective, absorptive, and polarization properties and the ability to perform remote sensing of CB agents are research themes of current and future interest.

Image Analysis

Target acquisition has been a key military capability but the speed and complexity of modern warfare has led to the need for automatic target recognition. The successes that have been obtained are limited to automatic target recognition (ATR), with a human making the final decision. These systems have been developed using heuristic and ad hoc techniques. The development of the theoretical underpinnings of automatic target recognition is needed. The objectives are to develop: (1) a set of scientific metrics that quantify image content, complexity, and structured clutter; (2) a set of metrics to describe the performance of image recognition and classification techniques; and (3) a set of performance models that can predict performance and allow optimization of system design.

Other Research Areas

Humans use a variety of sensor modalities to gather information about their world. The Army needs to develop a science for the integration of a variety of sensors such as conventional imaging systems, sound, chemical, etc., that will allow improved target recognition and discrimination.

c. Potential Military Benefits

These programs support advanced technology development to provide increased signal processing, signal display, sensor protection, and target acquisition. Novel and improved radiation sources and detectors will continue to provide new capabilities for the Army. In addition, atom optics are expected to provide new ultra sensitive detectors and clocks with applications that include global positioning systems and inertial navigation.

4. Chemistry

a. Strategy

Army basic research across all the chemical sciences is planned and coordinated annually by the Army Chemistry Coordinating Group. The Army Research Laboratory Weapons and Materials Research Directorate hosted the 1997 meeting in January at Aberdeen Proving Ground. Research briefings were presented by Army chemists from ARL Directorates for Weapons and Materials Research and for Sensors and Electron Devices, the Army research, development, and engineering (RD&E) centers at Picatinny Arsenal, Edgewood, and Natick, the Communications and Electronics Command, the U.S. Army Chemical Demilitarization and Remediation Activity, the Army Corps of Engineers WES, the U.S. Military Academy, and ARO. The ARO triennial in-depth long range strategy planning meeting for chemistry was last held in Janu-

ary 1995. The Army Chemistry Basic Research Program was briefed to Army leadership at the SARD/TRADOC Review and to DoD leadership at the Technology Area Review and Assessment (TARA) Review during March 1997. Army chemists performed joint planning with the Navy and Air Force at the annual Tri-Service Reliance Meeting in September 1996.

b. Major Research Areas

Following the Army chemistry long-range strategy, research in chemistry continues to focus on programs for which the Army has lead responsibility: CB defense, advanced materials, combustion, including explosives and propellants, power sources, obsolete weapon demilitarization, installation restoration, and pollution prevention.

Under Tri-Service Reliance, chemistry is divided into the subareas chemical synthesis and properties, and chemical processes.

Under chemical synthesis and properties, the Army has the lead for catalysts, reactive polymers, and dendrimers; the Army shares with the Navy and Air Force responsibility for functional polymers, energetic materials, power sources, nanostructures, sensors, lubricants, and elastomers.

Under processes, the Army has the lead for energetic materials ignition and combustion, CB decontamination and demilitarization, and diffusion in polymers. The Army shares responsibility for dynamics, corrosion, power sources, and sensors.

Army basic research on CB defense is carried out by ERDEC, NRDEC, and ARO and supports the Army CBDCOM development programs on sensors, protection, and decontamination. Recent ERDEC accomplishments include synthesis of polymers with highly active surfaces for molecular recognition of threat agents and decontaminants for the nerve agent VX. NRDEC has synthesized new polymer barriers against chemical agents. ARO investigators have developed powerful new catalysts for destruction of nerve and mustard agents.

Research on advanced materials is carried out by NRDEC, ARL, and ARO. Recent NRDEC accomplishments include flame and chemical resistant textiles with integration of advanced manufacturing techniques, and new biodegradable and nonpolluting polymers for functional composite materials. NRDEC materials are being evaluated by ARO investigators for laser eye protection. ARL scientists are studying use of dendritic molecules to improve fiber properties and adhesives. ARO and ARL are cooperating on a Small Business Innovation Research (SBIR) project for coatings to protect vehicles on the battlefield and on molecular-level design of new materials with chemical agent resistance and improved strength. ARO investigators are studying chemical diffusion in polymers for chemical defense, designing solvent resistant elastomers with flexibility at low temperatures, and developing nanomaterials from molecules that self-organize into structured coatings. ARO and ARL held a joint workshop on dentritic molecules in October 1996 at Michigan Molecular Institute.

Research on power sources is performed by ARL and ARO and supports development at Communications–Electronics Command (CECOM). ARL has made major improvements in lithium battery electrolytes, higher power density capacitors, and portable fuel cells. CECOM has established a Power Sources COE. ARO investigators have developed new fuel cell catalysts and membranes, designed and built microturbines for compact power (see Figure V–10), and developed new thermophotovoltaic materials. ARO manages the Defense Advanced Research Projects Agency (DARPA) Army-relevant programs in alkali metal thermal-electric converters (AMTECs). ARO has briefed the Compact Power program to SARD, AMC Headquarters, Dismounted Battlespace battle laboratory, *Army After Next*, and TRADOC Triennial Review and has held workshops seeking improved sources of hydrogen for hydrogen/air fuel cells. An ARO/CECOM/DARPA workshop

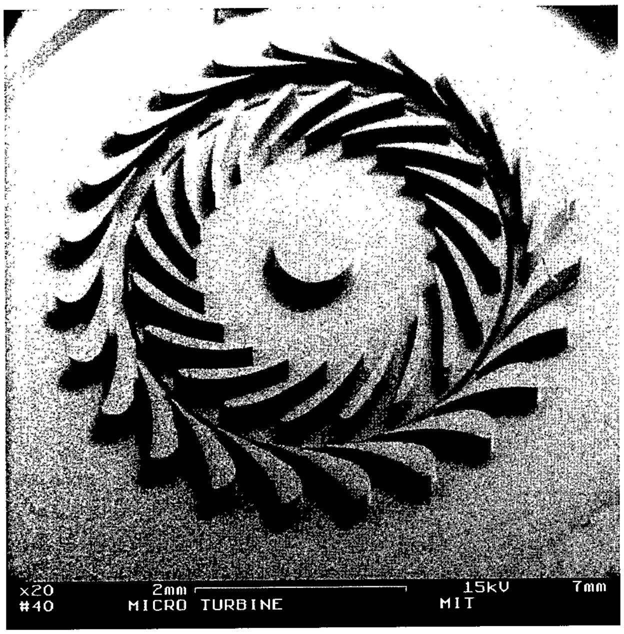


Figure V–10. Model Microturbine. Fabricated at MIT by ion-etching silicon. Diameter is approximately 2 mm. Research is part of the ARO program to power the *Army After Next* soldier.

on human generation of power will be held in the near future.

Research on explosives and propellants is performed by ARL, ARO, and the Armaments Research, Development, and Engineering Center (ARDEC) and supports development at Picatinny Arsenal and MICOM. Propellant burning rate models based on combustion data from ARO and ARL research are being transitioned into interior ballistic models for munitions design. Recent ARL accomplishments include new laser probes for propellant flames and theoretical calculations for propellant molecular dynamics. Related ARL research provides new options for fire suppression in military vehicles. ARO investigators are clarifying the pathways for decomposition of energetic materials. An ARL report (ARL–TR–1411) has been published on an ARO/ARL/ARDEC workshop to guide research for input into the Army Next Generation Interior Ballistics Model being developed at ARL.

Research on demilitarization, environmental remediation, pollution prevention, and chemical detection is performed by WES, ARL, ARO, and ERDEC and supports development by the Corps of Engineers, AMC, and the Army Demilitarization Activity. Recent accomplishments at WES include advanced prototype explosive sensors employing laser-induced breakdown and infrared spectroscopy for the Army site characterization and analysis penetrometer system (SCAPS). ARL accomplishments include plasma reactor design for nonpolluting paint removal and laser-based methods for detecting trace explosives and combustion products. ARL is also exploring supercritical fluid solvation to recycle propellants and nonpolluting coatings to retard corrosion. ARO investigators are developing improvements for ion mobility spectrometry—the current Army method for chemical weapon detection.

c. Potential Military Benefits

New materials will enhance soldier protection against ballistic and CB threats and provide stronger, lighter structures for vehicles. Compact electric power will support the soldier for longer missions with less to carry. New explosives and propellants will enhance effectiveness and reliability and reduce vulnerability. Work at ARL supports exploratory development at ARL and ARDEC and the ARL STO for Laser Igniter for Artillery Munitions and ARDEC STO for Energetic Materials/Warheads. New sensors will protect the soldier from explosive and CB threats. Weapons demilitarization and base clean-up research will reduce costs to manage Army inventory and remediate the environment. Research at WES supports the current STO on Explosives/Organics Treatment Technologies and planned STOs on Site Monitoring Systems and Advanced Explosives/Organics Treatment. CB defense research at Edgewood RD&E center is supported directly by DoD. That work supports Defense Technology Objectives (DTOs) in Advanced Lightweight Chemical Protection, Advanced Adsorption for Protection Applications, and Enhanced Respirator Filtration Technology.

5. Materials Science

a. Strategy

The overall objective of the materials science program is the elucidation of the fundamental relationships that link the composition, microstructure, defect structure, processing, and properties of materials. The work, although basic in nature, is focussed on those materials, material processes, and properties that improve the performance, increase the reliability, or reduce the cost of Army systems.

Research priorities are defined in the *Material Science Investment Strategy Plan,* which is prepared by the Army Materials Coordinating Group. This group is composed of scientists from ARO, participating RDECs, ARL directorates, and TRADOC. The plan outlines a strong multidisciplinary program in materials science that emphasizes research in five broad areas: manufacturing and processing of structural materials for Army vehicles and armaments, materials for armor and antiarmor, processing of functional (electronic, magnetic, and optical) materials, engineering of material surfaces, and nondestructive characterization of components for in service life assessment. Major themes are reflected in the discussions presented below.

b. Major Research Areas

The materials field is highly interdisciplinary, encompassing such diverse specialties as physical metallurgy, solid-state physics, chemistry, biology, penetration mechanics, surface science, and materials analysis. On the submicroscopic level, research is concerned with the manipulation of atoms and molecules and with the interactive forces that bind them. There is a strong emphasis on such topics as electronic and atomic structure, bonding character, and the many interactions of radiation and particles with condensed matter. At the microscopic level, the field is concerned with the effects of chemistry, microstructure, and phase transitions on the structural and functional properties of materials. At the macroscopic level, research is concerned with the continuum behavior of materials and composites. There are expanding opportunities for advancing the science of materials through continued integration and understanding of the interrelationships between the microscopic and macroscopic domains. This is reflected by the increasing integration of material modeling and numerical simulation into materials science.

New generations of materials with vastly improved properties are currently under development. Technology has now progressed to the point where it is possible to observe and manipulate materials at the atomic scale. This affords the opportunity to begin introducing much greater robustness into the design of materials and new possibilities for enhancing their performance. A growing interest of the Army is the design and fabrication of materials at submicron dimensions. New approaches to material synthesis based on self assembly of surfactants on surfaces, microcontact printing and micromolding, and flexible manufacturing approaches are under development. Examples of materials prepared by the microprinting process are shown in Figure V–11. This research is laying the foundations for the development of new generations of materials that will bear scant resemblance to the rudimentary materials technology that the Army depends on today. For example, a new class of "smart" materials is under development that will be able to sense its environment and significantly alter its properties to adapt to changing conditions. Likewise, molecular recognition and self-assembly techniques, which mimic natural processes, are being investigated as a synthesis route to new classes of multifunctional supramolecular systems.

c. Potential Military Benefits

Materials science research supports the entire Army materiel acquisition effort by ensuring that materials will exist that fully satisfy future mission requirements for improved firepower, mobility, armaments, communications, personnel protection, and logistics support. The emphasis is on developing new materials and processes

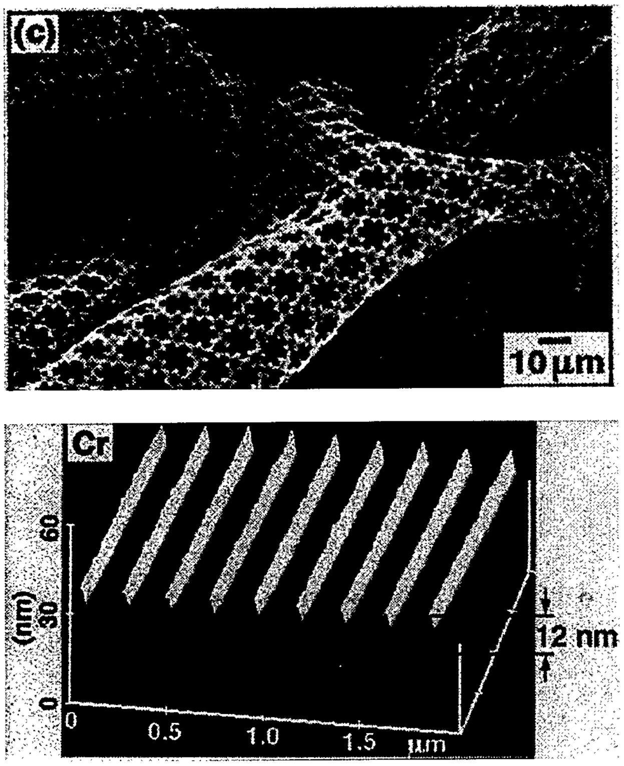


Figure V–11. Microprinting Process. Microprinting techniques have been developed for preparing patterned structures with submicron feature sizes.

that will significantly enhance materiel performance and reliability and reduce overall system costs. Major areas of impact include Army needs for individual soldier protection, armor/antiarmor, air and ground vehicles, bridging, shelters, communications, target acquisition, data processing, and power generation.

6. Electronics Research

a. Strategy

Electronics is an enabling technology for all future Army systems for the digitized battlefield of Force XXI and AAN. In particular, electronics research provides the seminal knowledge to explore new systems and enhanced capabilities for radar and radiometry, communications, C^2, fire control, electronic warfare, navigation, weapon guidance and seekers, and night vision devices. Army electronics research focuses on the generation of technology that will enable systems to function within the constraints imposed by the need for operation on small platforms such as the soldier, truck, armored vehicle, and helicopter used in highly mobile land warfare. This research provides the flow of ideas, concepts, and technology to the Army's developers to ensure the full integration of state-of-the-art electronics capabilities into advanced new systems in a timely and affordable manner. To achieve this goal and to maintain technological superiority, emphasis is placed on the investigation of a spectrum of near-term to far-term technologies. The research is reviewed, shared, transitioned and transferred through the Reliance Electronics Planning Group process, the technology area plans, TARA, and the Electronics Coordinating Group (ECOG) activities.

b. Major Research Areas

To satisfy the projected requirements, Army electronics research emphasize three broad needs:

- *Solid-state and optical electronics* with emphasis on ultrafast (terahertz switching speeds), ultradense electronics, and optoelectronic components.
- *Information electronics* with focus on systems for operation in adverse environments, designed to lighten, simplify, and reduce power consumption (low power electronics); communication and radar systems operating at millimeter-wave (MMW) through terahertz spectral region, and communications systems and networks and information processing for the digital battlefield.
- *Electromagnetics* with emphasis placed on conformal antennas, MMW systems, and systems exploiting optical MMW interactions.

Solid-State and Optical Electronics

Solid-state and optical electronics research in the near term includes advanced semiconductor devices supporting AAN applications, quasi-optical techniques for advanced millimeter and

subMMW systems, low-power electronics, advanced IR sensor concepts, short wavelength lasers, and related materials issues. In the long term, electronics research must provide for novel, robust, reliable multifunctional ultrafast/ultradense electronics, and optoelectronic components and architectures. By designing devices based on new physical principles of operation, expanded functionality, greater packing density and higher speed can be achieved. High-resolution, high-sensitivity, multicolor IR imaging arrays are required for target acquisition, recognition, and identification. Research thrusts include advanced materials, novel device structures, and appropriate system architectures. Ultrafast signal processing computing will require advances in light emitters. New system architectures are needed for increased data storage and efficient optical processing. As shown in Figure V–12, a key element in solid-state and optical electronics research is atomic-level feature control to provide devices that will meet the Army's future technology needs in device integration and information capacity.

Information Electronics

Information electronics research is driven by the profound growth of battlefield information sources and the complexity and need to process and communicate that information in near real time for the digital battlefield concepts. Force XXI and AAN operational concepts call for a highly mobile force whose success is dependent on reliable voice, data, and video communications on the move and information with the minimum latency and varying quality of service requirements to ensure quick decisions and synchronous operations. Research is conducted in network management, network protocols and architectures, message routing including flow and congestion control, forwarding algorithms, advanced switching technology and interfacing, and integration of heterogeneous networks. Methods for the design of large, distributed, mobile spread-spectrum packet radio network architectures, protocols, routing, and control are investigated. The use of adaptive array antennas in networks to provide spatial reuse of limited spectrum, to increase network throughput capability, to increase interference and jamming resistance, and to lower transmit power requirements is investigated. Information fusion includes both sensor and data fusion techniques. It encompasses a number of scientific disciplines including signal, image, and speech processing; decision theory; distributed heterogeneous databases; and intelligent systems. It allows the

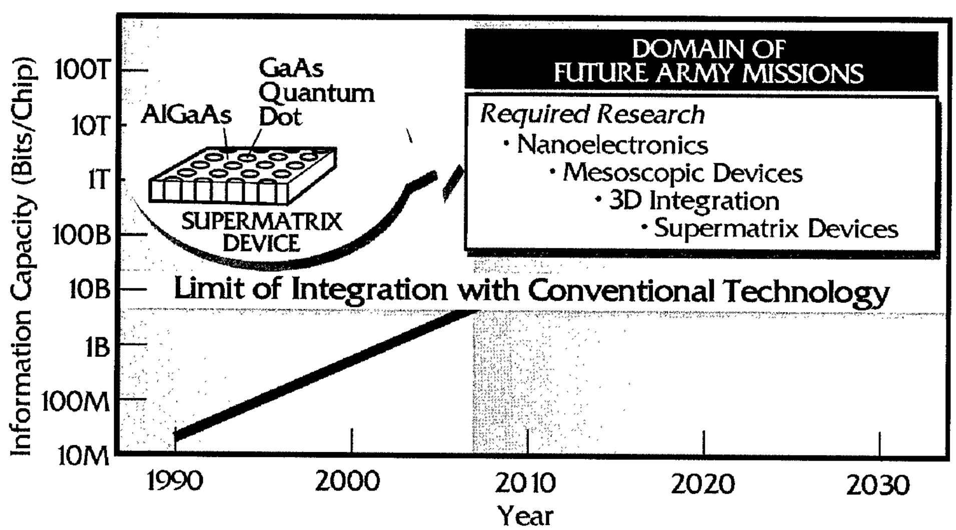


Figure V–12. Electronics Research

improvement of accuracy and reliability of information, reduces the quantity and confusion of data, and provides real-time tactical command and control information assessment capability.

Electromagnetics

Electromagnetics research focuses on issues unique to Army needs such as circuit integration, antennas, and propagation that will enable Army exploitation of the terahertz, MMW, and high-frequency microwave portion of the spectrum for communications and radar and seeker systems for the digitized battlefield. Power-combining techniques such as quasi-optics are critical in enabling moderate or high power MMW systems with the advantages of solid-state electronics. Optical control of microwave and millimeter circuits provides the opportunity for low weight, low-cost control of antenna arrays. Novel concepts for high efficiency, low-loss antennas and antenna arrays are of importance, including active antennas.

c. Potential Military Benefits

A key element in electronics research is atomic-level feature control to provide devices that will meet the Army's future technology needs in device integration and information capacity. Enhanced performance and functionality of future electronics will lead to faster, more portable, and more reliable systems for target identification; intelligent systems for better command and control of fire support missions; miniaturized computers and displays with improved processing capability; data fusion of multidomain, compact, smart sensor suites; enhanced timing and location systems for autonomous weapons; optimized man–machine interface; ultrafast information processing in extremely small, massively parallel processors; high-data rate photonic communications; and ultra-small integrated multifunctional sensors for the soldier. Real-time signal processing is critical to communications, adaptive array antennas, and signal intercept as well as image analysis, target acquisition, and information fusion. Signal and information processing are used in the implementation of image, radar, speech, antenna, and communication processing systems for applications in target detection, identification and tracking; guidance and control; fire control; and communication. Research in fast, high-resolution, null- and beam-steering and compact adaptive antennas will provide low-signature communications and improved signal intercept capability.

7. Mechanical Sciences

a. Strategy

The Army's reliance on mobile systems to perform its mission requires a major research effort in the mechanical sciences to provide the technology base that will enable the development of vehicles and their armaments with significantly advanced capabilities to meet the requirements of the AAN. The Army Mechanics Coordinating Group (MECOG) has developed a strategy for focusing the Army's future research programs in the mechanical sciences on the most opportune and important areas. The strategy takes advantage of the reliance process with the Navy and Air Force and is peer reviewed at the annual DDR&E TARA.

b. Major Research Areas

The MECOG developed the appropriate research thrusts and assigned priorities, while regularly coordinating in-house and extramural research efforts in the four major fields of the mechanical sciences that are critical to Army interests:

- Structures and dynamics
- Solid mechanics
- Fluid dynamics
- Combustion and propulsion.

Structures and Dynamics

In the area of structures and dynamics, the research topic areas are structural dynamics and simulation and air vehicle dynamics. The higher

priority research thrusts in structural dynamics and simulation are ground vehicle and multibody dynamics, structural damping, and smart structures and active controls. For air vehicle dynamics, the higher priority research thrusts are integrated aeromechanics analysis, rotorcraft numerical analysis, helicopter blade loads and dynamics, and projectile aeroelasticity. Multidisciplinary research on advanced active control of coupled rotorcraft vibration and aeroacoustics offers a significant potential reduction in rotorcraft vibration and acoustic radiation for the AAN (see Figure V–13).

Solid Mechanics

In the area of solid mechanics, the research topic areas are the mechanical behavior of materials, the integrity and reliability of structures, and tribology. The classes of materials of interest are functional gradient materials and heterogeneous materials. In mechanical behavior, the higher priority research thrusts are material responses in the state of nonequilibrium or transient states as in impact and penetration mechanics and damage initiation/propagation. Within this thrust is a special basic research program on smart resilient structures involving novel material concepts, material behavior, responsive mechanisms, and analytical tools that provide the fundamental underpinnings for a technology-to-engineering development program for responsive armor concepts needed for AAN (see illustration). Additionally, the mechanical response under coupled effects of electric, magnetic, and thermal fields is of great interest. The research in the area of integrity and reliability of structures focuses on damage tolerance, damage control, and life prediction. In the area of tribology, dynamic friction, lubrication, and surface topology in low heat rejection environments are emphasized.

Fluid Dynamics

For fluid dynamics, the research areas are unsteady aerodynamics, aeroacoustics, and vortex dominated flows. The higher priority research thrusts in unsteady aerodynamics are dynamic stall/unsteady separation, maneuvering missiles/projectiles, and rotating stall and surge in turbomachinery. In aeroacoustics, the research thrusts are on helicopter blade noise

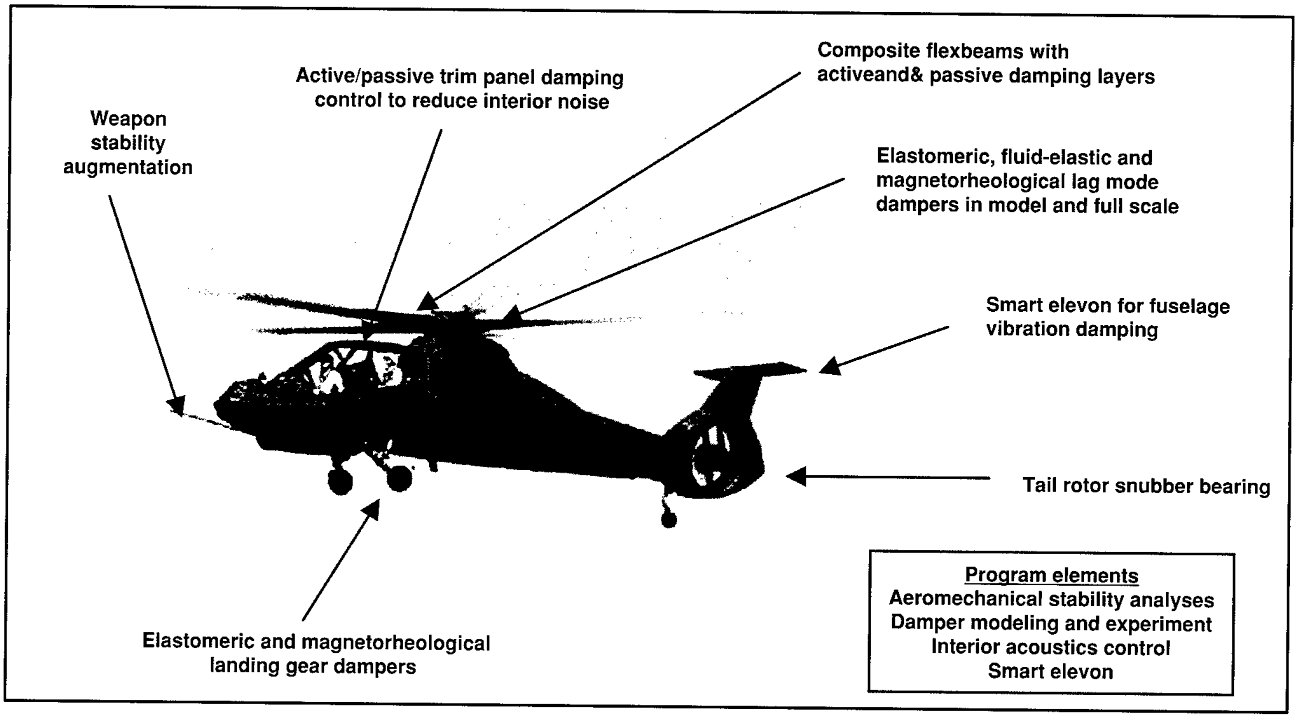


Figure V–13. Passive/Active Damping Control for Rotorcraft Systems

generation, propagation, and control; and in vortex dominated flows, they are on rotorcraft wakes and interactional aerodynamics.

Combustion and Propulsion

For combustion and propulsion, the research topic areas are small gas turbine engine propulsion technology, reciprocating engine technology, solid gun propulsion, liquid gun propulsion, and novel gun propulsion. The higher priority research thrusts in small gas turbine engine propulsion are in critical combustion processes, enhanced optimization, and integration of miniature sensors and active controls. For reciprocating engine technology, the higher priority research thrusts are in ultra-low heat rejection environments, enhanced air utilization, and cold start phenomena. For solid gun propulsion, the major thrusts are in ignition and combustion dynamics and high performance solid propellant charge concepts. For liquid gun propulsion, they are in atomization and spray combustion, ignition, and combustion mechanics and instability, hazards, and vulnerability. The higher priority thrusts in novel gun propulsion are electrothermal-chemical (ETC) propulsion, active control mechanisms, and novel ignition mechanisms.

c. Potential Military Benefits

Research supported in the mechanical sciences provides the necessary tools to enable prediction, design, simulation, and assessment of future Army air/ground vehicles, their power plants, and armament systems, which results in increased performance, reliability, sustainment, and mobility. In particular, advanced, higher performance rotorcraft and vehicle gas turbine engines, stable weapon system platforms, accurate supply and weapon-on-target delivery capabilities, resilient structures for heavy/light fighting vehicles, vehicle structural reliability and survivability, more energetic and reliable gun propellants, advanced electromagnetic gun propulsion systems, high power density diesel engines, weapon failure analysis/prediction, and multibody vehicle simulation capabilities, for example, can be expected from the Army research program. Mechanical sciences have a significant impact on five technology areas (Chapter IV): aerospace propulsion and power, air and space vehicles, individual survivability and sustainability, conventional weapons, and ground vehicles.

8. Atmospheric Sciences

a. Strategy

The atmospheric environment impacts every aspect of Army operations. Fog, rain, snow, and aerosols and smokes from battlefield sources are a few obvious factors influencing Army strategy, mobility, logistics, and weapons delivery. Prior, quantitative knowledge of present and future environmental conditions, consequences, and limitations is essential for intelligence preparation of the battlefield, for developing improved weapon systems, for using weather conditions as a force multiplier, and for enhancing the Army's "all-weather" capability.

Under Project Reliance, the Army has the primary responsibility for scientific issues concerning the atmospheric boundary layer over the land. Furthermore, the Army has the responsibility for providing environmental data for its own needs at battlefield and smaller scales. Better capabilities for predicting and using weather effects as force multipliers require basic understanding of the physical processes of the atmosphere on scales ranging from continental to the engagement scales and the ability to communicate them effectively in oral, visual, or electronic media for a variety of practical, user purposes. The Army's Atmospheric Sciences Coordinating Group, with representatives from ARO, ARL directorates, Test and Evaluation Command (TECOM), National Oceanic and Atmospheric Administration (NOAA), academia, and industry, developed a strategic plan for focusing future research by identifying and assigning priorities to promising basic research thrusts.

b. Major Research Areas

Present and future research focuses principally on the atmospheric boundary layer—where the Army operates—at higher time and space resolution than ever before. Basic research in the atmospheric sciences is multidisciplinary, using understanding of electromagnetic and acoustic propagation in the atmosphere, fluid dynamics and turbulence, radiative energy transfer, and thermodynamics of mixed phases of water to assess the natural and induced environments over the land.

Development of a capability for remote sensing of the atmospheric boundary layer for high resolution of wind velocity, temperature, and moisture in four dimensions will continue as a major research interest. The sensed data should provide quantitative information on the inhomogeneity of the atmosphere as a propagation (electromagnetic and acoustic) medium and as a dispersing medium for natural and induced aerosols. The instruments for remotely measuring atmospheric boundary layer properties at time and space scales affecting Army interests increase the time and space resolution of atmospheric effects and properties (Figure V–14).

Propagation research concentrates on developing physically based models of atmospheric propagation in a variety of real environments. The models address electromagnetic frequencies from the ultraviolet through MMW and acoustic frequencies from 1 to 1,000 hertz (Hz). Developing reliable imaging models for predicting atmospheric effects on sensors or system imaging performance, especially in inhomogeneous conditions, will improve evaluations of systems before going to field tests or deployment. The models will also be used to examine atmospheric effects on digital communications and ATR performance, and to improve ATR algorithm development. Also, the application of spectroscopy to

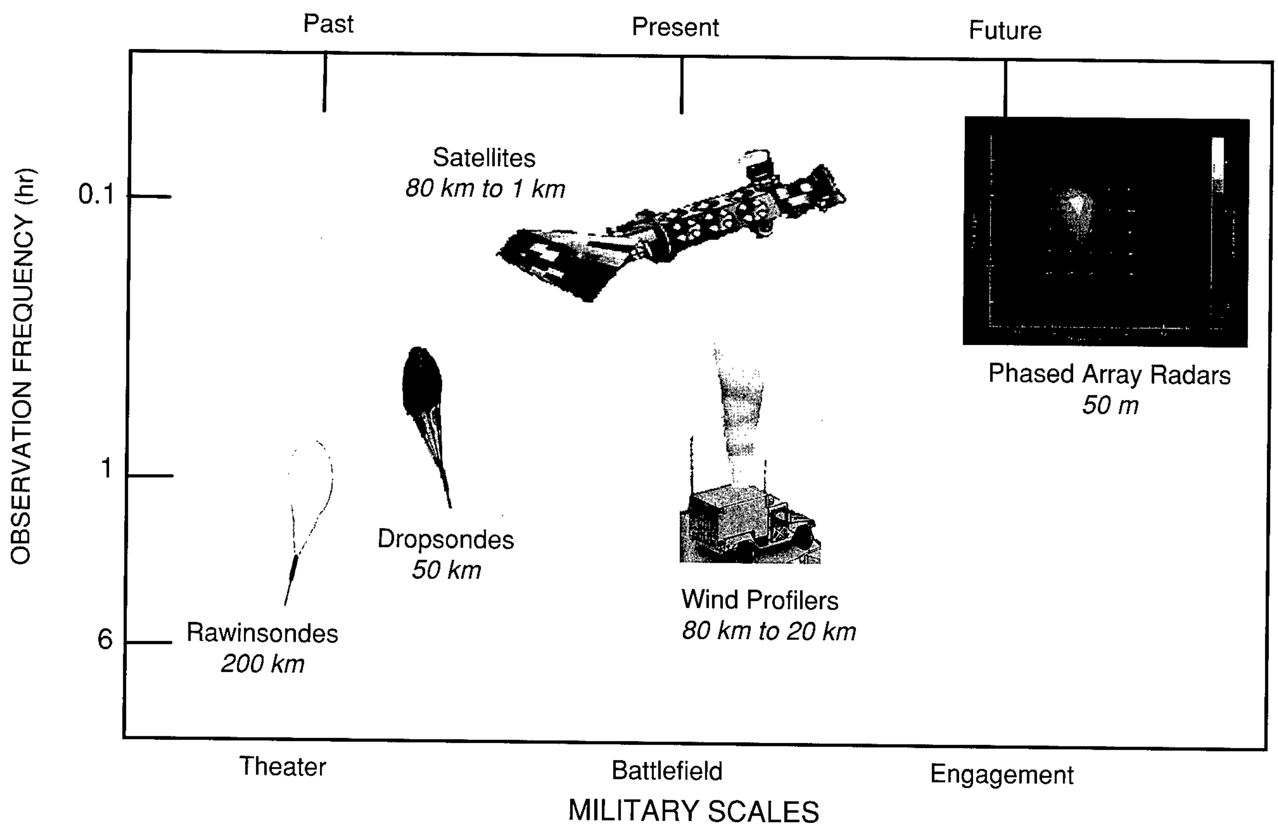


Figure V–14. Sensing Atmospheric Properties

earth sensing is developing a major library of reflectance and radiance data to support the modeling and rapid detection of natural and manmade features, including camouflage.

Research efforts in understanding the detection, identification, and quantification of chemical and biological aerosols will continue. Research thrusts in this area are expected in the development of laboratory capabilities that are later transferred to field applications or techniques.

c. Potential Military Benefits

Boundary layer meteorology research serves all services through improved characterization (parameterizations) of boundary layer processes over land in weather prediction models. It specifically supports multiple functions of the Army's Integrated Meteorological System (IMETS) in intelligence preparation of the battlefield. Research in turbulent dispersion of aerosols leads to a significantly improved dispersion model applicable to open detonation/open burning of munitions; for improved prediction of transport and diffusion of nuclear, biological, and chemical (NBC) materials on short time and space scales, over varied terrain shapes and ground covers, and all times of day; and for modeling effectiveness of smoke and other obscurants in realistic scenarios.

Remote sensing of wind fields will also enable detection of hazardous winds in aircraft landing zones, in paradrop zones, above urban areas, and in accidental release of hazardous gases or aerosols. Active and passive remote sensing research is essential to detection of objects in snow or on the ground, modeling, and rapid detection of natural and manmade features, including camouflage.

9. Terrestrial Sciences

a. Strategy

Army doctrine has long dictated that commanders know the terrain. Coupled with weather, the resulting variety and dynamics of the terrain surface impact all aspects of the Army mission. The broad range of features and conditions found in cold region, mountain, temperate, desert, and tropical climates of the world can be either a formidable barrier or significant advantage for our forces. The key determinants are, first, a knowledge of terrain characteristics and processes and, second, the ability to incorporate that knowledge into our planning, operations, system development, training, and doctrine. The topographic, geological, climatological, and hydrological character of the are critical to mobility/countermobility, logistics, communications, survivability, and troop and weapons effectiveness. The digital battlefield requires detailed and sophisticated information about topography as well as terrain features and conditions. Environmental information and models need to be integrated with systems models to develop the ability to simulate and forecast system and unit performance. These capabilities are fundamental to the development of materiel that can perform effectively in worldwide environments, as well as doctrine that is appropriate for the wide range of conditions that might confront a force projection Army.

Within the context of a force projection Army, terrain conditions are of paramount importance to mission planning, field mobility and logistics, systems performance, and unit effectiveness. The force-projection, precision-strike Army of the 21st century will be able to use and control terrain more effectively than an opponent. In this context, the Army will have two superior capabilities. The first will be full situational awareness through an integrated capability to acquire, automatically process, analyze, and display terrain data—derived from a variety of different space, airborne, and ground-deployed remote sensing platforms—in real time that can be distributed to at all levels of command, both in-theater and the continental United States (CONUS), at the level of resolution required. The second will be a capability for realistic, dynamic terrain for interactive training and mission planning and rehearsal. Three types of 3D digital terrain information will

be available: topography, natural features and manmade objects, and short-term battlefield conditions and dynamics. These force-multiplying capabilities will enhance a commander's ability to visualize a battlefield at multiple resolutions and execute combat operations using an efficient decision-making cycle much more rapidly and effectively than an adversary. They will also improve a planner's capability to manipulate and evaluate information about terrain and provide a trainer the functionality to correctly incorporate realistic terrain into distributed, interactive simulation. Dynamic, 3D terrain models will be the enabling foundation for interservice, intelligent autonomous weapon systems. Additionally, the Army of the 21st century will have a capability for rapid deployment to perform military and humanitarian operations worldwide. These forces will rely on enhanced battlefield awareness and timing to conduct pulsed, well-coordinated massing of forces to quickly overwhelm enemy forces with minimal loss of manpower and material. An essential component for operational success is superior mobility of deployed military forces. Ground forces will be smaller, lighter, and more capable of precision maneuvers at high tempo with reduced logistics encumbrance. A capability to effectively model and predict vehicular mobility in real time under current environmental and battlefield conditions is critical to this objective.

Terrestrial sciences research within the Army, which is directed toward meeting the above-stated objectives, is highly multidisciplinary in nature. The vision, long-term strategy, and research priorities for the terrestrial sciences are defined in the Environmental Sciences Strategy Plan, which is prepared by the Environmental Sciences Coordinating Group. This Group is composed of scientists from ARO, the Corps of Engineers laboratories (Construction Engineering Research Laboratory (CERL), Cold Regions Research and Engineering Laboratory (CRREL), Topographic Engineering Center (TEC), and WES), academia, and industry. This plan outlines a strong multidisciplinary research program in the terrestrial sciences that emphasizes research in three broad areas:

- Terrain Characterization and Analysis (topography and terrain).
- Hydrodynamics and Surficial Processes (hydrometeorology, surface and subsurface hydrology, hydraulics, geomorphology; and coastal processes).
- Geotechnical Engineering (snow, ice and frozen ground, geophysical site characterization, vehicle–terrain interaction, geotechnical engineering).

Major themes of the plan are reflected in the following paragraphs.

b. Major Research Areas

Terrain Characterization and Analysis

Characterization of the surface geometry and terrain features of remote or inaccessible areas is needed to enhance planning and tactical decision making, as well as tailoring equipment to the challenges of the natural environment. Fundamental data on the distribution and character of natural and manmade features, together with information about the dynamic condition of the terrain, are required for rapid mapping and such information must be coupled to models that quantify dominant physical processes to allow temporal forecasts of the conditions to be faced by soldiers and materiel. Enhanced remote sensing data acquisition capabilities (Figure V–15), system-organization and neural network theory, and advanced numerical methods are used to synthesize topography and terrain database information. The earth's surface features and materials interact dramatically with the boundary layer and weather systems, producing a highly sophisticated background within which targets are embedded. A knowledge of the many energy exchanges as a function of terrain character and climate, as well as their impact on the appearance of terrain scenes to sensing devices used for reconnaissance and target acquisition, is critical to both the development and deployment of these systems. Modeling of the physical pro-

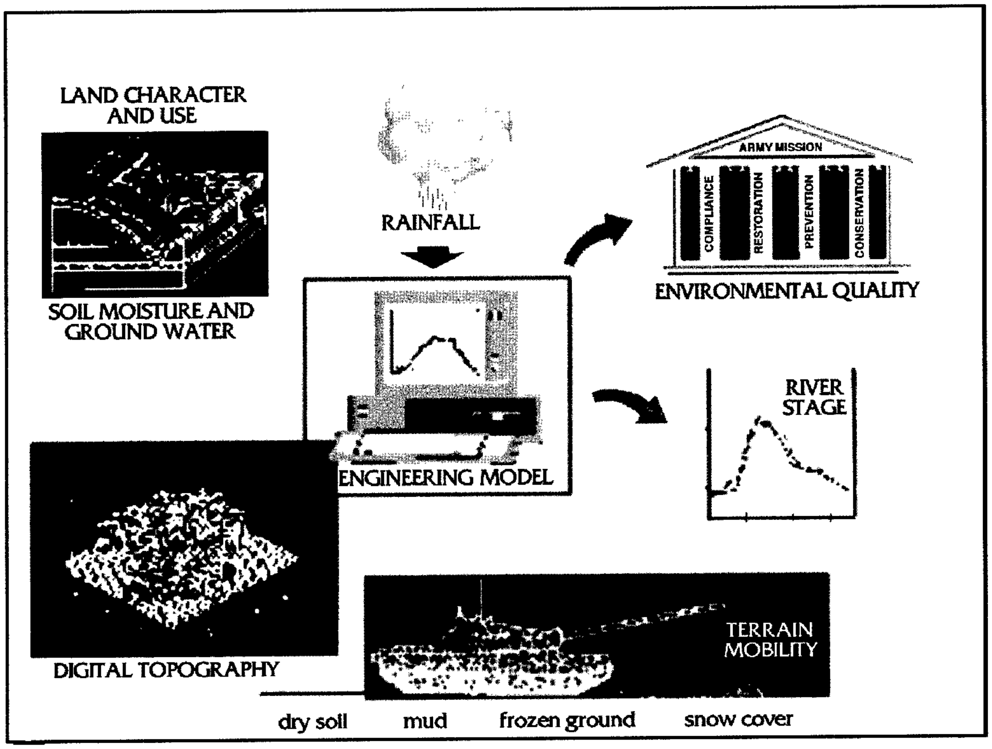


Figure V–15. Terrestrial Sciences Thrusts

cesses operating on the Earth's surface is essential for the design of autonomous systems and the ability to realistically consider dynamic environmental effects in system performance and training simulations and in wargames. No single factor has more influence on the performance or the ability to accomplish future missions with emerging autonomous or aided smart systems.

Hydrodynamics and Surficial Processes

Research in hydrodynamics and surficial processes addresses two thematic areas. The first relates to the hydrologic cycle and focuses on hydrometeorology, rainfall-runoff dynamics, surface and groundwater hydrology, and fluvial hydraulics. This area includes research that seeks to understand the fundamental nature of subsurface flow and mass transport, numerically model this complex process, and describe the interaction of surface water and ground water systems. The second relates to the geomorphological character of the surficial environment and focuses primarily on physical processes operating in arid/semi-arid, tropical, and coastal environments. A knowledge of the topography and physical character of landscape leads to the ability to estimate hydrologic/physical response and, therefore, an ability to accomplish specific activities within the range of environmental conditions that might occur in different localities, seasons, and weather. Hydrometeorological conditions and the surface hydrologic regime are determining factors in mobility/countermobility, thus impacting surface strength, creating barriers to movement, and/or at times allowing movement over normally inaccessible terrain.

Geotechnical Engineering

Geotechnical engineering research focuses on the strength and behavior of natural materials at a variety of scales. Soil is the dominant surficial material of terrain and a highly heterogeneous material that usually is distributed both horizontally and vertically in a nonuniform manner. Its strength and deformation properties are highly variable due to both the intrinsic heterogeneity of soil formation processes and moisture content over small spatial scales. Because nearly all

Army operations take place on the Earth's surface, a thorough understanding of the physical character of soil and its behavior under different environmental conditions, and the development of appropriate constitutive models, is required. Operational mobility and successful geotechnical engineering rely on a knowledge of the type and distribution of soils at a small scale, as well as an understanding of the physical properties and behavior of different soil types under different environmental conditions. Research on soil dynamics and structural mechanics is focused on the nonlinear response of deformable soils to transient loadings by vehicles, constitutive behavior of geological/structural materials to weapons effects, a determination of the response of granular materials to loading, and the failure mechanisms of pavement systems. Physics-based principles and quantitative approaches are needed to provide predictive estimates of soil behavior and to model the process of vehicle–terrain interaction. There is a special emphasis on the cold/alpine regions, where research is directed toward the physics, mechanics, and dynamics of snow, ice, and frozen ground in the context of the impacts of winter conditions on most equipment and soldier activities.

In the context of the Army's mission of environmental stewardship there is a need for basic research related to environmental quality. Concern about environmental damage that has resulted from military activities requires improved technological capabilities for the characterization, analysis, and remediation of contaminated sites. Important in this context is research that addresses the response of the landscape to modification, research which seeks to understand the fundamental nature of subsurface flow and mass transport, and research into improved technologies for site characterization that would provide insight into the character of the near subsurface environment without recourse to conventional drilling. (See Hydrodynamics and Surficial Processes and Geotechnical Engineering topics above.)

c. Potential Military Benefits

Terrestrial sciences research is directly supporting current Army Science and Technology Objectives (STOs) in Vehicle–Terrain Interaction, Digital Terrain Data Generation and Update Capability, and Conservation. The complexity of the terrestrial environment can be a positive factor that the warfighter can leverage to operational/tactical advantage, when the features and physical processes occurring therein are understood at a fundamental level. Improved topographic and terrain information and an improved understanding of the physical nature and dynamic behavior of the surface environment—particularly regarding possible impacts on the simulating, planning and execution of military operations—can be a dramatic force multiplier. Knowledge about the detailed character of a terrain and a capability to estimate when and where specific physical events or conditions will occur can be a great tactical advantage, in terms of both operational capability and preparedness. For example, an understanding of vehicle–terrain interactions is necessary for mobility modeling, an ability to remotely estimate precipitation and/or snowmelt infiltration and runoff is necessary to forecast hydrologic stage for river crossing operations, and an ability to predict sea-state conditions and nearshore morphology is essential to successful logistics-over-the-shore operations. Research in support of the environmental stewardship mission will lead to the Army conducting its activities in concordance with federal statutes, the cleanup of contaminated sites on military installations, well-managed and sustainable training lands natural and the preservation of cultural resources on military installations.

10. Medical Research

a. Strategy

Military biomedical research is concerned with sustaining warfighter capabilities in the face of extraordinary battle and nonbattle threats

through the preservation of combatants' health and optimal mission capabilities. Basic biomedical research focuses on health threats of military importance, supporting the DoD mission to provide health support and services to U.S. armed forces. The Army mission differs from that of other large national and international medical research programs, as well as that of the private sector. The National Institutes of Health, for example, focus primarily on diseases affecting the U.S. civilian population. Similarly, private industry is driven by civilian disease demographics and profit incentives. In contrast, military research is oriented to the unique health threats posed by weapons of mass destruction, and by the unusual geographic, environmental, and operational environments in which the Army must function. Recognizing the large investment in basic biomedical sciences within the civilian sector, the Army positions its biomedical basic research programs to exploit, rather than sustain, the medical technology base. A variety of cooperative agreements with industry and other government agencies play an integral role in this strategy (Chapter VII). Efforts are intensively managed to push technologies toward transition. Joint coordination and cooperation within and among various functional areas prevent duplication of effort and are accomplished through the Armed Services Biomedical Research Evaluation and Management (ASBREM) Committee and its subordinate joint technology coordinating groups.

b. Major Research Areas

Medical basic research programs ensure that cutting-edge scientific advances are fully and effectively integrated into resolution of military-unique challenges with the four functional areas of medical capability most critical to maintaining effective medical technological superiority: (1) infectious diseases of military importance; (2) combat casualty care; (3) Army operational medicine; and (4) medical CB defense. This functionally aligned research investment ensures against technological surprises, manmade or evolutionary, that could overwhelm medical countermeasures to threats to the health and performance of our armed forces.

Basic research in infectious diseases of military importance concentrates on prevention, diagnosis, control, and treatment of infectious diseases affecting readiness or deployment. Molecular biology will facilitate rational design and discovery of vaccines and prophylactic drugs to prevent illness, new vaccine delivery systems, and rapid diagnostic tests based on genetic probes. Special emphasis will be placed on sequencing the genomes of disease-causing organisms, characterizing interactions between pathogenic organisms and their hosts, and on DNA-based vaccine strategies that offer potential for addressing multiple threat agents.

Basic research in combat casualty care focuses on the biological responses to traumatic conditions, especially such conditions as low blood flow and poor oxygen delivery that occur following heavy blood loss. These studies identify potential diagnostic and prognostic indicators and sites for medical intervention and contribute to the development of suitable models of injury that can be used to evaluate drugs, biologicals, devices, and medical techniques that may be beneficial in immediate treatment, resuscitative surgery, or critical care during sustained evacuation. Emphasis is also placed on developing signal-processing techniques and models of physiological response that can be integrated into intelligent life-support systems.

Basic research within the Army operational medicine functional area provides an understanding of the pathophysiology of environmental and occupational threats affecting soldier health and performance. These threats include extreme climatic or terrestrial environments, the rigors of military operations themselves (e.g., continuous operations, deployment stress), and system-associated health hazards (e.g., electromagnetic or nonionizing radiation, noise, vibration, blasts, and toxic chemical byproducts). Most products in this functional area are informational and serve as guidelines for materiel and

combat developers (e.g., exposure standards for noise or vibration, work-rest cycles), but advances in neurosciences and molecular biology may lead to medical products that reduce susceptibility to fatigue or injury. Basic research must keep pace with the hazards of future weapons systems and doctrinal solutions as they are developed. Research will include the analysis of changes in visual performance in response to operational stressors to improve the design of displays and operator selection criteria, investigation of biomarkers that can indicate exposure to hazardous (nonthreat) chemicals, and identification of nutritional and pharmacological strategies that may reduce the incidence and severity of altitude-related injuries.

Medical CB defense focuses on military threat agents of biological or chemical origin. Medical biological defense basic research focuses on biochemical, immunological, or microbiological characterization of biological warfare threat agents and toxins; understanding of disease processes caused by them; identification of the mechanisms of protective immunity; and discovery and characterization of suitable model systems. Basic research in medical chemical defense provides an understanding of the pathophysiology of threat agents and elucidates threat agent mechanisms of toxicity so that rational countermeasure strategies directed against those threats can be designed. Research is ongoing to identify methods of stimulating host immunologic protection against a broad spectrum of biological warfare agents, rather than protection against specific agents. Also under investigation are medical diagnostics based on DNA analysis, bioengineered vaccines with multiple immunogenic properties, and approaches to block the actions of biological threat agents on target receptor sites. Reduction of incapacitating effects caused by chemical warfare agents remains a high priority research area, drawing on advances in molecular biology to develop more effective and less debilitating medical countermeasures. Although present approaches are showing promise for prevention of nerve agent toxicity, molecular biological approaches may also provide safe and effective prophylaxes and treatments for the effects of blister agents.

c. Potential Military Benefits

These basic research programs provide the foundation for medical technological superiority in support of the National Military Strategy. Figure V–16 illustrates the impact that biomedical research can have on warfighting capability. In peace, medical technological superiority is a critical element of deterrence, bolsters confidence of our coalition partners, and is the foundation of soldier readiness. In crisis, medical technological superiority ensures that threats to the health of the force are not a limiting factor on military options normally available to the National Command Authority. Military health care delivery also enables superior performance in a variety of operations other than war, providing humanitarian assistance, disaster relief, and nation building, which contributes to national and regional stability. In war, it amplifies individual combat effectiveness, minimizes casualties, and diminishes death and disability rates among those who become casualties.

11. Biological Sciences

a. Strategy

Basic research in the biosciences greatly increases our ability to understand and manipulate those aspects of the biological world that impact soldier sustainment and survival, and to identify and characterize biological materials and processes for future exploitation in materiel systems. In order to plan and execute high quality research relevant to Army needs in the biological sciences, an ARO Life Sciences Program Coordination and Planning Group including scientists from ARO, ARL, Army RDECs, Medical Research and Materiel Command (MRMC), and the Army Corps of Engineers (ACE) was established. Functioning as an advanced planning process team, this group developed a strategy for focusing research program activity in the biosciences to emphasize an appropriate balance

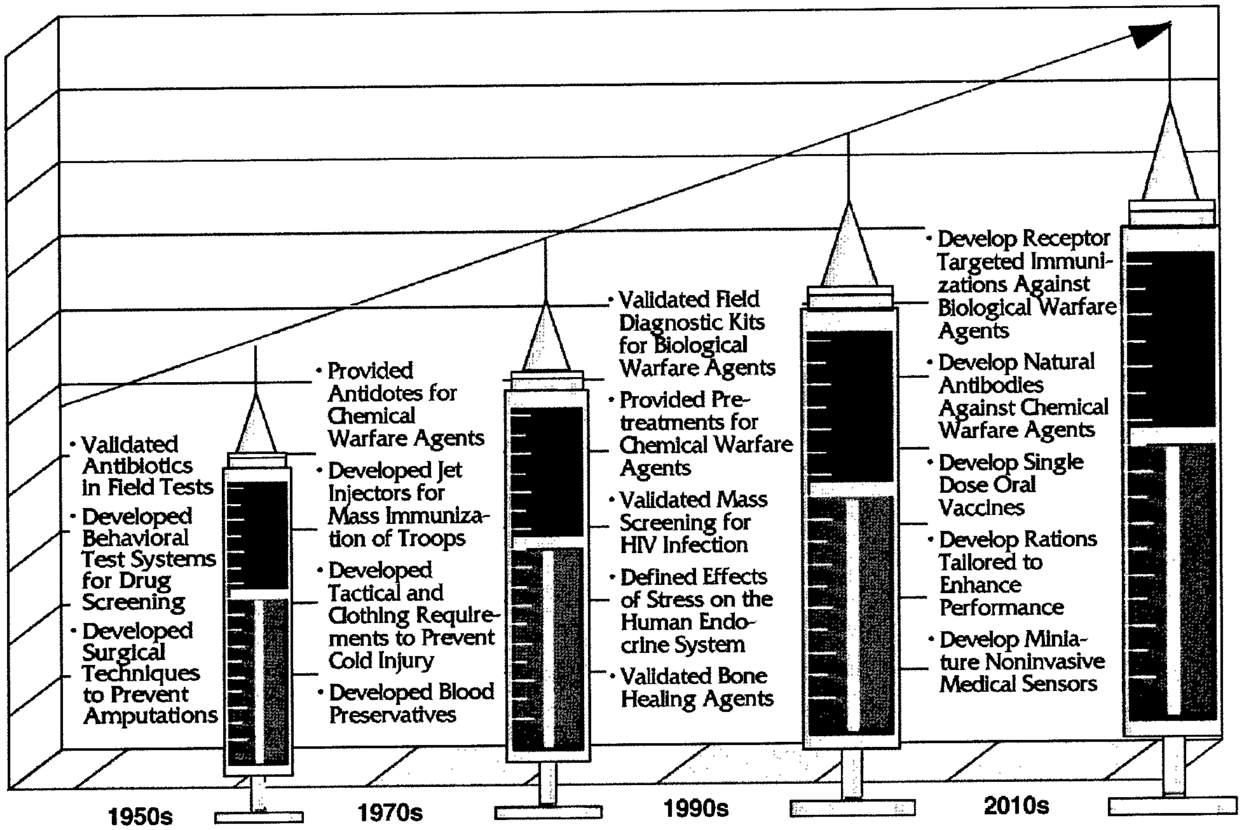


Figure V–16. Basic Research in Military Medicine

between (1) capture of breakthrough scientific opportunities from the biological sciences research community, and (2) alignment with Army and DoD science and technology objectives, and support of Army current and future demonstrations and fielded items where applicable. While aimed at enabling novel capabilities, program efforts focus on providing the means to increase economic and environmental affordability in Army materiel production, on lessening the logistics burden, and on preventing the deleterious effects of chemical, biological, and physical agents from interfering with Army operations. Implementation of this strategy involves support of basic research in a number of subdisciplines including, but not limited to biochemistry, biophysics, molecular biology and genetics, cell biology, microbiology, physiology and pharmacology, encompassing studies at the molecular, cellular, and systems level.

b. Major Research Areas

Basic Research in Biotechnology

Basic research in biotechnology is directed toward fundamental studies that have as their goal the generation of new knowledge relevant to application of cell derived tools to biological production processes. These studies seek to expand our understanding of biological macromolecular interactions. They provide information on gene expression and its regulation, on enzyme mechanisms and on the general nature of biological catalysis and metabolic pathways, and on other forms of subcellular chemical processing.

Optimization of Physical Principles

Optimization of physical principles in biological systems has as its main objective the discovery and description of novel theoretical prin-

ciples and mechanisms, or materials with extraordinary properties, from biological sources (i.e., lessons from nature). The aim is to identify and characterize, as completely as possible, those biological processes and structures that might be used directly in, or provide conceptual models for, development of engineered systems with potential for military application.

Physiology and Performance

Physiology and performance provides for basic research on biological response and adaptation to environmental signals, and strategies that organisms use to survive adversity. Research efforts seek to uncover strategies for limiting performance degradation during military operations, some of which place unprecedented physiological demands on the soldier. Research issues concerning improvements in soldier sustainment are addressed here as well, including those dealing with innovative technology for rations.

Biodegradation

Biodegradation addresses the identification and characterization of cells and cell systems capable of breaking down materials relevant to Army activities. It includes attempts at better understanding the mechanisms underlying biodegradative processes in normal, extreme, and engineered environments, and the properties of materials that make them susceptible or resistant to biological attack. Knowledge gained applies to bioremediation of toxic wastes at military sites as well as to protection of military materiel from biodeterioration.

Defense Against Chemical and Biological Agents

Defense against chemical and biological agents focuses on basic biosciences research on (1) mechanisms of enzymatic or enzyme-mimetic catalysis for detoxification of threat agents, (2) the modes of action of potential agents on physiological targets, with implications both for biologically based concepts for detection of threat agents and for protection based on a better understanding of agent–target interaction, and (3) rapid identification of biologicals using novel analytical techniques.

c. Potential Military Benefits

The potential for use of cellular genetic and biochemical manipulation in biotechnology for economically favorable and environmentally benign manufacturing processes and for bioremediative strategies is great. Biosciences research will enable metabolic engineering and bioprocessing to make significant contributions to Army and DoD missions and to the commercial sector for products and processes for off the shelf use by the military.

Research on biomolecular materials and processes enables the discovery of novel theoretical principles and of products with extraordinary properties. These provide insight into the foundations of such phenomena as self-assembly, molecular recognition, catalysis, and energy transfer. Understanding will lead to unique military, industrial, and consumer applications in such areas as sensors, smart materials, robotics, low-observable technology, and biomimetic processing for composites. Likewise, the biological world offers many examples of exquisitely integrated signal transduction and multimodal information processing. Fundamental knowledge pertaining to how biological systems accomplish this will continue to have substantial impact on the design of engineered information systems.

Attempts to better understand the genetic and biochemical mechanisms in diverse strategies of adaptation that organisms use to survive harsh environments or adverse conditions offer the hope of providing the soldier a means for coping with physiological stresses. Studies in food science provide the means to better understand nutrient conversion for cellular energy and neurotransmitter function, and to enable control of microbial growth and stabilization of structural integrity during food processing, contributing not only to improved soldier satisfaction and enhanced long-term acceptability of combat

rations but also to improved soldier performance and endurance.

In general, these and other studies show great promise in terms of building a foundation for a number of emerging technologies (see Figure V–17).

12. Behavioral, Cognitive, and Neural Sciences

a. Strategy

The Army behavioral, cognitive, and neural sciences (BCNS) program centers on soldiers in units, and seeks a scientific understanding of the factors that can enhance or diminish human performance. The research program is executed by two agencies, the ARI for the Behavioral and Social Sciences and the Human Research and Engineering Directorate (HRED) of the ARL. Duplication of research is prevented through frequent meeting of the two agencies. Interservice coordination is effected through Reliance agreements. The research program is evaluated in the TARA review.

b. Major Research Areas

Basic BCNS research addresses the following major topic areas:

- Training research (e.g., learning, memory, skill transfer, simulation, mental models)
- Personnel research (e.g., recruitment, classification, assignment, societal issues)
- Leadership research (e.g., development, skills, social structures)
- Visual processes
- Auditory processes
- Stress and cognitive processes (e.g., stress, psychophysiology, endurance)
- Soldier interface research (e.g., human computer interaction).

The training research program provides data, models, and theories to better understand how individuals learn and process information. An understanding of cognitive processes is essential to the optimal design of training programs and, ultimately, the human–systems interface. Several controllable factors influence the speed at which an individual learns. Other factors can influence the rate at which trained skills are forgotten. Yet another set of factors significantly influence the ability of the individual to transfer skills learned under one set of conditions, such as in a simulator, to slightly different conditions, such as in using real equipment. Results from this research are used to develop effective technologies for training soldiers. Effective training is defined by

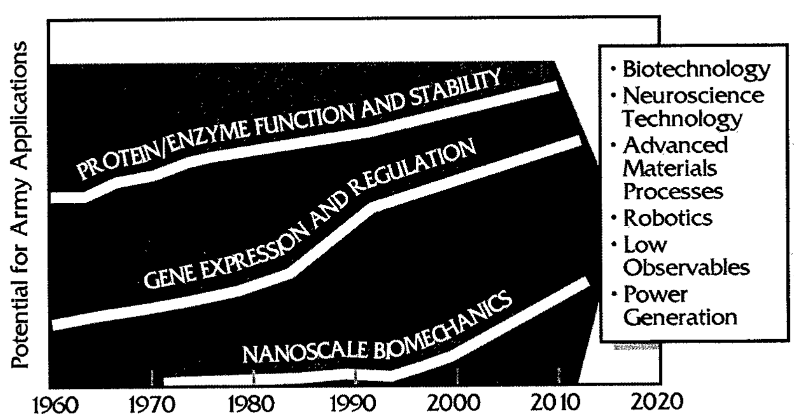


Figure V–17. Technologies Emerging From Biological Sciences

its cost, the permanence of the training, and its ability to transfer to real equipment under realistic job conditions.

The goal of the personnel research program is to provide an understanding of the principles that underlie successful applied personnel research. The formation and maintenance of attitudes underlie recruitment, family opinion of the Army, and personal opinions and behavior relevant to diversity issues. Aptitudes underlie issues related to selection and assignment of personnel. Results from this research are used for additional applied research and often have direct implications for policy.

Research in the elements of leadership provides knowledge both on the essentials of successful leadership performance and the ability to develop effective training of leadership skills. The history of warfare has many examples of how seemingly less effective forces have prevailed in battle as a result of more effective leadership. Effective leadership includes the ability to manage others, coordinate activities, inspire a group, train individuals and teams, and make decisions.

The goal of the research program in visual processes is to better understand visual and related processes such as divided attention, particularly as they impact on the use of head-mounted displays. There are several unique Army issues related to the use of head-mounted displays caused by the demands of task conditions and performance. This research will also support the Army's increasing emphasis on night operations, teleoperations, and the training and battlefield control systems afforded by advances in distributed interactive simulation. A better understanding of visual processes is needed if the Army is to effectively exploit advances in optics and infrared technologies.

Research in the auditory processes provides the knowledge to protect, support, and extend soldiers' auditory capability on the battlefield. The battlefield provides a unique challenge for audition. High noise levels and impulse noise that threaten auditory sensitivity compete with low level sound signals that provide important information to the soldier. Well-designed human–equipment interfaces must consider the characteristics of the auditory system for effective individual utilization of new technologies. The mathematical model of the ear, being considered as an international standard, allows more complete and timely exploration of these interactions (see Figure V–18).

The stress and cognitive processes research program addresses the issue of how various types of stress affect individual functions. Stress can result from high rates of physical or mental effort, physical exhaustion, or emotional response to threat. Although stress is a common response category for different causes, the actual stress responses and consequences are different in each case. Research is designed to address each type of stress and its relation to aspects of cognitive and other soldier performance, with the eventual goal of developing effective remediation strategies (e.g., staffing, training, unit design changes) to offset the often negative consequences of stress on behavior.

The goal of the research program on soldier interfaces is to better understand the principles that enable the soldier and teams to manage the vast quantities of data that will flow across the digitized battlefield. This program, accomplished jointly with industry and universities as part of the federated laboratory project, will provide the Army with the ability to optimize the human component of battle management and utilize the information advantage provided by advanced sensors and improved communication.

c. Potential Military Benefits

The overall goal of this research is the optimization of human performance and the human–system interface. The research is guided by the requirements of the Army about 25 years from now as envisioned by the AAN, which envisions small teams working relatively independently on a dispersed battlefield. In this environ-

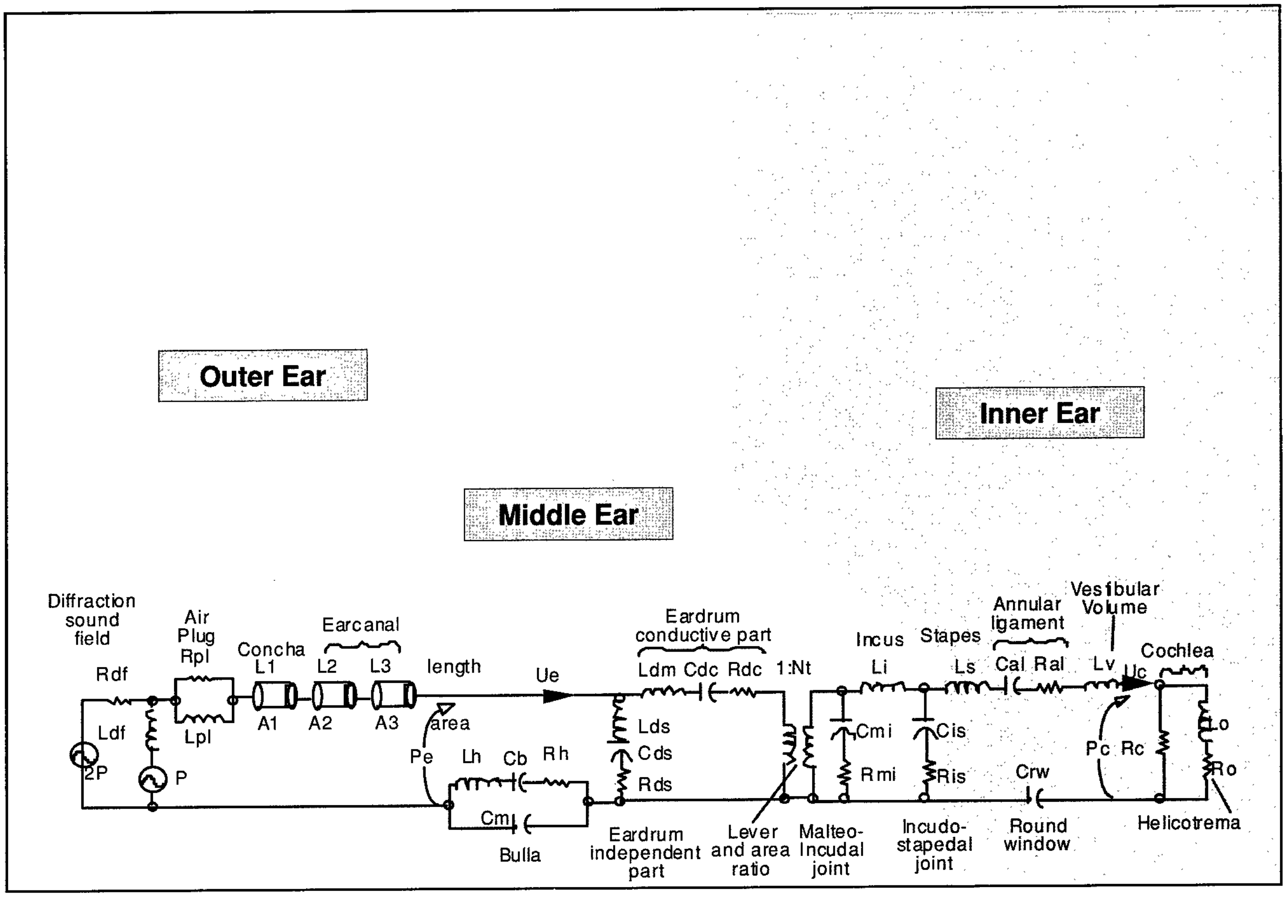


Figure V–18. Mathematical Model of the Ear

ment, a premium will be placed on soldier competency, initiative, and leadership. The combat effectiveness of the teams will be enhanced through an effective understanding of the battlefield and the ability to coordinate precision fire. The AAN vision can be realized through the improved personnel assignment and more effective training utilizing advanced simulation capabilities. Soldiers will operate equipment more effectively because of improved interfaces that consider their abilities and expectations. Finally, the confusion and stress of the battlefield will be controlled through more effective leadership and an improved understanding of the causes and effects of stress. The link between ARI and HRED research helps ensure that fielded systems are not just operable but cost effective.

D. SUMMARY

The Army basic research program is an integrated in-house and extramural research program. The in-house laboratory programs are driven by mission needs; the extramural program is chartered to provide a balance between long-term extramural research foci-pursued through Army-funded academic COEs and industry-led federated laboratories—and unanticipated, more forward-looking research windows of scientific opportunity—pursued through the single investigator program. ARO and the management at the Army's laboratories and RD&E organizations deliberate and coordinate in partnership to establish, implement, and meet overall Army research objectives. Despite

receiving only a small portion of DoD's basic research budget, the Army derives the maximum return on investment from its research program through its high degree of integration. Table V–7 summarizes how the scientific research areas described in this chapter support the six SROs defined to date; Table V–8 depicts how these scientific research areas support the ten technology areas described in Chapter IV.

The research areas described in the preceding sections of this chapter are dynamic and continuously updated. Programs are reviewed by multiservice organizations, by Army battle laboratory personnel, by peer reviews, and by coordinating groups established for each of the scientific areas. To illustrate the dynamic nature of the scientific areas, Table V–9 summarizes how certain research areas are receiving new or increasing emphasis and highlights recent accomplishments.

Much of the research supported by the U.S. Army is undertaken by distinguished scientists and engineers at American colleges and universities, as detailed in previous sections of this chapter. Not only does the Army benefit from the accomplishments of these people but they themselves receive honors bestowed on them by their peers. Table V–10 summarizes some of the awards received during the past year by the individuals shown for their research sponsored by the U.S. Army.

The Army's science base is an essential foundation for the technology on which the Army's ability to meet future threats depends. Research for the Army is performed by a blend of university and in-house components that are uniquely suited to the Army's special requirements. Because of the fundamental role of the science base in shaping the Army's technological future, the Army is committed to strongly support basic research.

Table V–7. Where Scientific Research Areas Support Strategic Research Objectives

Scientific Research Area	Strategic Research Objectives: Biomimetics	Nanoscience	Smart Materials	Mobile Wireless Communications	Intelligent Systems	Compact Power Sources
1. Mathematical Sciences	●		●	○	●	
2. Computer and Information Sciences	●	●		○	●	○
3. Physics	●	●	○			●
4. Chemistry	●	●	○			●
5. Materials Sciences	●	●	●	○		●
6. Electronics Research	●	●	●	●	●	●
7. Mechanical Sciences	○	○	●			●
8. Atmospheric Sciences				○	○	
9. Terrestrial Sciences					○	
10. Medical Research	○				●	○
11. Biological Sciences	●	○	○		●	○
12. Behavioral, Cognitive, and Neural Sciences	○			○	●	

● Significant impact ○ Some impact

Table V–8. Impact of Basic Research Areas on the Chapter IV Technology Areas

Chapter IV (6.2) Technology Area	Chapter V (6.1) Research Areas: Mathematical Sciences	Computer and Information Sciences	Physics	Chemistry	Materials Science	Electronics Research	Mechanical Sciences	Atmospheric Sciences	Terrestrial Sciences	Medical Research	Biological Sciences	Behavioral, Cognitive, and Neural Science
Aerospace Propulsion and Power				●	●		●					
Air Vehicles		○			●		●		○			
Chemical and Biological Defense		○	○	●	○	○		●		●	●	
Individual Survivability and Sustainability	○		○	●	●	○	●			●	●	●
Command, Control, and Communications	●	●	●		○	●			○	○	○	●
Computing and Software	○	●	○		○	●				○		○
Conventional Weapons			●	●	●	○	●			○	○	
Electronic Devices			●	○	●	●					○	
Electronic Warfare/Directed Energy Weapons			●	○	○	●		●				
Civil Engineering and Environmental Quality				●	○		○	○	●	○	●	
Battlespace Environments						○		●	●	○		○
Human Systems Interfaces		○			○	○				●	●	●
Personnel, Performance, and Training		○				○				●	●	●
Materials, Processes, and Structures		○	○	●	●	●	○				●	
Medical and Biomedical Science and Technology				○		○			●	●	●	○
Sensors		○	●	●	●	●		●	○	○	○	
Ground Vehicles				○	●		●					
Manufacturing Science and Technology	○	○	○		●	○					○	
Modeling and Simulation	●	●				●		○	●			○

● Significant impact ○ Some impact

Table V–9. Illustrations of the Dynamic Nature of Research Programs

Research Areas	New Emphasis	Increasing Emphasis	Accomplishments
Mathematics and Computer Science	Image analysis Quantum computing	Nanotechnology	Graph partitioner 10 times faster than state-of-the-art spectral methods Geometric modeling, dynamic display, and fast rendering techniques Controllers for dynamic simulations of human/soldier systems
Physics	Dendritic macromolecules Microturbines and thermophotovoltaics	Diffusion and permeability in polymers Chemical process modeling Direct oxidation fuel cells CB detection	Conduction via single quantum eigenstates in coulomb-blockaded quantum dots Performance bounds for ATR Elimination of optical self-focusing by population trapping 3D wire mesh photonic crystals
Chemistry	Mathematics of biological/natural systems	Hybrid systems Image analysis Numerical methods for stochastic differential equations	Environmentally friendly solvent/chemical agent resistant elastomers Mechanisms of carbon hydrogen bond oxidation in homogeneous catalysis High aspect ratio etching of microturbine wheels Enhanced chemical agent reactivity of layered nanoscale metal oxides Complete hydrodechlorination of 1, 1, 1 trichloroethane and reduction of half mustard
Materials Science	Electroluminescent porous silicon Molecular-based nanostructures Dendrimer polymers (modeling/simulation)	High performance fibers Nonequilibrium processing Biomimetic processing	In situ liquid crystal polymer (LCP)/thermoplastic microcomposites Flux-trapped superconducting magnets Diffusion-enhanced adhesion Modulated diamond-like carbon films High strength, tough micro-layered polymer composites
Electronics	Demining Low energy electronics design for mobile platforms	Optical control of array antennas Image analysis and terahertz electronics Low power electronics with RF emphasis	Multicarrier direct sequence code division multiaccess with lower bit error rate First principles simulation using full band Monte Carlo Field-controlled piezo-tuning of microdevices

Table V–9. Illustrations of the Dynamic Nature of Research Programs (continued)

Research Areas	New Emphasis	Increasing Emphasis	Accomplishments
Mechanics	Aerothermophysics for theater missile defense (TMD) missiles Sensing, actuation, control for advanced engines Real-time simulation of multi-body dynamics Novel structural damping concepts Reliability of structures/materials	Advanced active control—rotorcraft vibration and aero-acoustic coupling High pressure hydrocarbon combustion Composites in high strain rates Damage mechanics	Fast Floquet theory for computational determination of a helicopter's stability in forward flight First planar laser-induced fluorescence (PLIF) images of shock-initiated combustion in supersonic gas mixtures Extension of shear band studies into 2D velocity and rate of energy dissipation in moving adiabatic shear bands First detailed mean and turbulence measurements in supersonic base flows with base bleed
Atmospheric and Terrestrial Sciences	Terrain analysis and visualization Landscape process dynamics	Stable boundary layer Acoustic signal variability in turbulent atmosphere Terrain–vehicle interaction Ice adhesion and mechanics (macroscale)	Theory for turbulent scattering of acoustic waves in intermittent turbulence Theory of dynamic drag law for high-resolution atmospheric boundary condition Development of CB aerosol detector First generation, mathematically rigorous contact mechanics model for soil tire interaction Prototype cone penetrometer system for in-situ measurements of hydraulic conductivity
Medical	Receptor-targeted drugs and antibodies Oxygen free radical scavengers Malaria Genone Project	Genetic engineering Microencapsulation of vaccines and drugs Performance-enhancing nutrients	Oral treatment (arteether) for drug-resistant malaria Topical treatment (paramomycin) for cutaneous leishmaniasis Diagnostic skin test for leishmaniasis
Biological Sciences	Plant biotechnology Response and adaptation to environmental signals Enzymatic functions at extreme temperatures	Biodegradative microbiology Biodetection Nanoscale biomechanics Biocatalysis	New detection signature for pathogenic bacteria Isolation of genes required for establishing and maintaining hibernation Crystal structures of gene repressor and its complexes Incorporation of nonnatural amino acids into artificial proteins
Behavioral, Cognitive, and Neural Sciences	Perceptual processes Attention fixation	Night vision Long term skill retention Multimodal interfaces	Depth perception cue isolation and enhancement Determined role of commitment to performance

Table V–10. Some of the Awards Received During the Past Year by Scientists and Engineers for Research Sponsored by the U.S. Army

Individual	Affiliation	Award Received
Acton, Prof. S. T.	Oklahoma State University	Eta Kappa Nu Young Electrical Engineer Award
Aggarwal, Prof. J.	Washington University	IEEE Computer Society Technical Achievement Award
Bajcsy, Prof. R.	University of Pennsylvania	National Academy of Engineering
Bancroft, COL W. H.	U.S. Army Medical Research and Materiel Command	AMSUS Gorgas Medal
Bierman, Prof. P.	University of Vermont	Geological Society of America Donath Medal
Burke, COL D. S.	Walter Reed Army Institute of Research	President, American Society of Tropical Medicine and Hygiene
Chlamtac, Prof. I.	University of Texas	Assoc of Computing Machinery Fellow
Chopra, Prof. I.	University of Maryland	American Helicopter Society Fellow
Chu, Prof. B.	State University of New York, Stony Brook	Society of Polymer Science Award, Japan
Cover, Prof. T. M.	Stanford University	IEEE Richard W. Hamming Medal for 1997
Curl, Prof. R.	Rice University	Nobel Prize in Chemistry (shared)
Cushman, Prof. J. H.	Purdue University	American Geophysical Union Fellow
Dunn, Prof. B.	University of California, Los Angeles	Allied Sponsored Research Award; Fellow, American Ceramics Society
Fiedler, Prof. F.	University of Washington	Distinguished Scientific Contributions Award from the Society for Industrial and Organizational Psychology
Fields, Prof. L.	City University of New York	Fellow, American Psychological Association
Fridovich, Prof. I.	Duke University	Franklin Institute Elliot Cresson Medal
Friedman, Prof. P.	University of California, Los Angeles	1996 AIAA Structures Structural Dynamics and Materials Award
Gessow, Prof. A.	University of Maryland	American Helicopter Society Lifetime Accomplishment Award
Grenander, Prof. U.	Brown University	National Academy of Science
Hall, Prof. H.	University of Arizona	American Chemical Society Cooperative Research Award in Polymer Science and Engineering
Happer, Prof. W.	Princeton University	American Physical Society H.P. Broida Prize
Ho, Prof. C. M.	University of California, Los Angeles	National Academy of Engineering
Honig, Prof. M.	Northwestern University	IEEE Fellow
Kolb, Dr. C. E.	Aerodyne Research Inc.	1997 American Chemical Society Award for Creative Advances in Environmental Science and Technology
Lakshminaryana, Prof. B.	Pennsylvania State University	ASME 1996 Fluid Dynamics Award
McIntosh, Prof. R. E.	University of Massachusetts	National Academy of Engineering
MacKnight, Prof. W.	University of Massachusetts	1997 American Chemical Society Polymer Research Award

Table V–10. Some of the Awards Received During the Past Year by Scientists and Engineers for Research Sponsored by the U.S. Army (continued)

Individual	Affiliation	Award Received
Montgomery, Prof. W. W.	Western Michigan University	Geological Society of America Award for Outstanding Student Research
Pandolf, Dr. K.	U.S. Army Research Institute of Environmental Medicine	President-Elect, International Society for Adaptive Medicine
Perepezko, Prof. J.	University of Wisconsin	Minerals, Metals and Materials Society Bruce Chalmers Award
Pope, Prof. G.	University of Texas, Austin	Society of Petroleum Engineers Distinguished Achievement Award
Popovic, Prof.	University of Colorado, Boulder	International Union of Radio Science Koga Award
Rebeiz, Prof G.	University of Michigan	IEEE Fellow
Rogers, Prof. C.	Virginia Polytechnic Institute	ASME Fellow
Russell, Prof. T.	University of Colorado, Denver	Campus Researcher of the Year Award for 1996
Rutledge, Prof. D.	California Institute of Technology	1997 IEEE Microwave Theory and Techniques Society Distinguished Educator Award
Schmaljohn, Dr. C. S.	U.S. Army Medical Research Institute of Infectious Diseases	Dalyrmple–Young Award, American Society of Tropical Medicine and Hygiene
Segal, Prof. D.	University of Maryland	Presidential appointee to the Board of Visitors, United States Military Academy (USMA)
Sirignano, Prof. W.	Univ of California, Irvine	Combustion Institute Egarton Gold Medal
Smalley, Prof. R.	Rice University	Nobel Prize in Chemistry (shared)
Smith, Prof. J. A.	Princeton University	University Engineering Council Teaching Award for 1996
Tsvankin, Prof. I.	Colorado School of Mines	Society of Exploration Geophysicists Virgil Kaufman Gold Medal

CHAPTER VI

INFRASTRUCTURE

CONTENTS

CHAPTER VI

INFRASTRUCTURE

A major element of the Army strategy for military technology is a strong, viable in-house research capability. Laboratories and research, development, and engineering centers (RDECs) are the key organizations responsible for technical leadership, scientific advancement, and support for the acquisition process. The organizational structure of the current Army science and technology (S&T) program is illustrated in Figure VI–1, the funding breakdown by organization is shown in Figure VI–2, and the geographical locations of research sites are shown in Figure VI–3.

The Army is committed to maintaining world-class research, development, and testing facilities. We equip these facilities with modern equipment and hire and retain personnel capable of utilizing the tools provided. This infrastructure is committed to meeting the developmental needs of the land combat force and providing for the effective transfer of developing technologies to the civil as well as military sectors.

The Army continues a multifaceted approach to support and maintain its infrastructure. Appropriated funds are used to construct, pur-

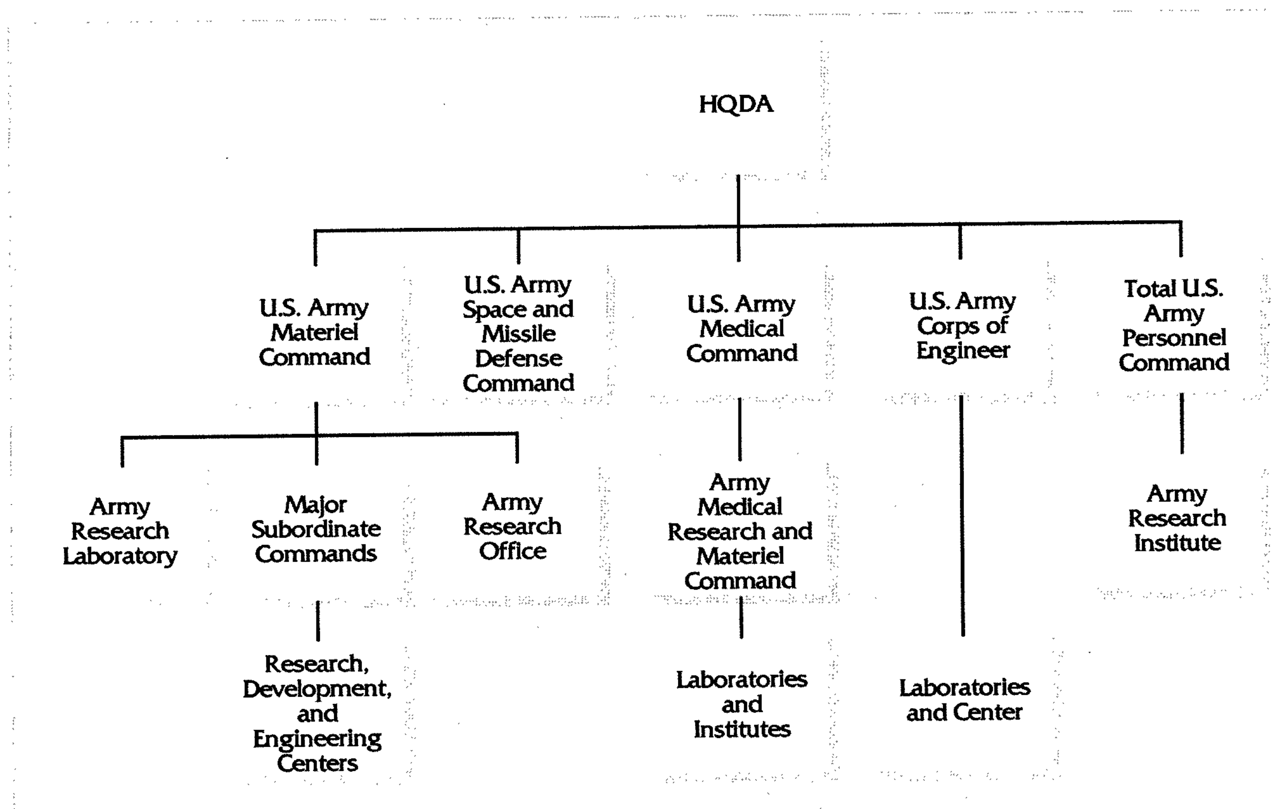
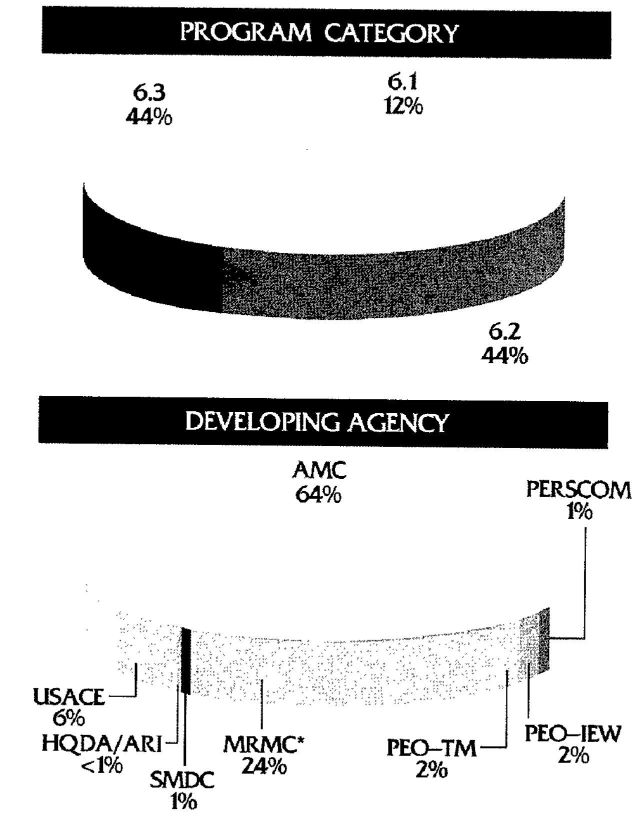


Figure VI–1. Army Science and Technology Organization



*Includes significant congressional enhancements.

Figure VI–2. Army Science and Technology Funding Distribution, FY98

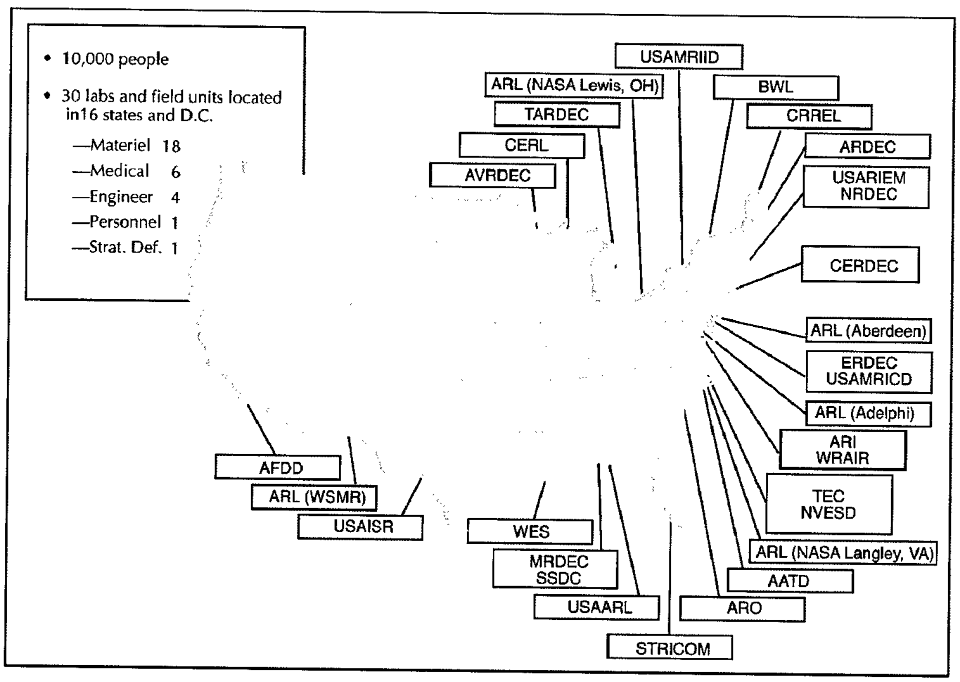


Figure VI–3. Army Research and Development Resources Involved in Science and Technology

chase, and maintain unique equipment and facilities. As appropriate, equipment items or facilities that are developed during a specific program are retained and modified to meet additional R&D needs. The Army continues to expand modeling and simulation (M&S) capacities to reduce costs of materiel development, improve safety, and shorten developmental schedules. Finally, the Army leverages the facility investments of external organizations by sharing or otherwise using those facilities that contribute to Army objectives.

The Army's supporting R&D infrastructure consists of (1) the federated laboratory initiative, (2) physical facilities and equipment, (3) distributed simulation, (4) modeling/software/testbeds, (5) information technology/communications, and (6) personnel.

This chapter addresses these capabilities at Army installations and those available to the Army through working relationships with other organizations. Examples of successful operations and descriptions of how the Army has benefited are presented. Also highlighted are Army plans to enhance and improve existing capabilities through investment and leveraging.

Chapters III through V outline what the Army plans to accomplish in terms of science, technology, and development to meet the Army's future warfighting needs. How well this is accomplished depends largely on the ability of management to apply state-of-the-art scientific tools, equipment and facilities, and personnel resources in meeting the stated goals.

Keeping the infrastructure up to date demands a monetary investment that is consistent with the needs of the materiel, combat, operational and training development communities. It also involves internal investment in S&T to provide added technology to meet Army modernization objectives. The Science and Technology Objectives (STOs) in Volume II enhance our ability to support materiel development and support advances in gaming and modeling battlefield operations and doctrine.

A. FEDERATED LABORATORY INITIATIVE

The Army Research Laboratory (ARL) instituted the federated laboratory concept in FY95. The federated laboratory initiative is a unique combination of the best features of the government and private sectors. Chapters V and VII provide more detail on federated laboratories.

B. PHYSICAL FACILITIES AND EQUIPMENT

1. Physical Plant

The Army has invested in special facilities that range from small, uniquely designed, state-of-the-art laboratories such as the Corps of Engineers' Ice Engineering Laboratory to large-scale facilities using sophisticated instrumentation required to measure and support the evaluation of myriad system prototypes and weapon systems under development, such as those at Aberdeen Proving Ground (APG).

The Army Research Office (ARO), a part of the Army Materiel Command (AMC), but located in Research Triangle Park, North Carolina, is dedicated to promoting basic research. Its proximity to Duke University, North Carolina state University, and the University of North Carolina facilitates its mission.

Many facilities have been developed in partnership or under a leveraging agreement with other services, government organizations, industry, or academia.

The Simulation, Training, and Instrumentation Command (STRICOM) is collocated with the Naval Air Warfare Training Systems Division. STRICOM, the Navy command, the University of Central Florida's Institute for Simulation and Training, and many local defense contractors make Orlando, Florida, a center of the Department of Defense simulation activities.

ARL is continuing to upgrade facilities to accommodate consolidations and incoming R&D activities that are relocating under the 1991 Base

Realignment and Closure (BRAC) Commission decision. Construction at Aldephi Laboratory Center will accommodate the mandated BRAC91 relocation of functions from White Sands Missile Range, New Mexico; Fort Monmouth, New Jersey; and Fort Belvoir, Virginia.

The total construction program will add approximately 320,000 square feet to the installation at a cost of $77 million. The $60 million physical sciences building will house the sensor and electronic device personnel relocating from Fort Monmouth, the Sensors Directorate relocating from Fort Belvoir, and the advanced simulation and high-performance computing (ASHPC) directorate.

The R&D computer center will allow the ASHPC directorate to connect with the high-performance and simulation computers located at APG. Completion of the physical sciences building is scheduled for July 1998. The recently completed, high-bay facility accommodates the Information Science and Technology Directorate's research in atmospheric science. It provides loading, transfer, and testing capabilities of special meteorological field research equipment.

Construction at APG includes a materials research facility, out-of-laboratory facility, and the target assembly and storage facility. The recently completed Materials Research Facility (MRF) supports a wide range of basic material research as well as research by other defense, government, and private agency customers.

The out-of-laboratory facility provides for electromagnetic pulse survivability and vulnerability analysis and testing capabilities for all of DoD. Vulnerabilities are found through exposure to low-level fields and then verified with current injection devices.

The Target Assembly and Storage Facility at APG accommodates the assembly and storage of classified targets and also provides the specialized capability to work with heavy-metal armor such as depleted uranium.

The U.S. Army Space and Missile Defense Command (SMDC) operates or funds several support capabilities that enhance Army S&T with data and information derived from assessments, analyses, experiments, and tests of both strategic and tactical systems. The Space and Missile Defense Battle Laboratory (SMDBL) has a high-performance computing distribution center consisting of the Advanced Research Center (ARC) and the Simulation Center (SC), both in Huntsville, Alabama. These centers are contractor-operated facilities that consist of government-owned, general-purpose application development processors that provide a wide range of architectures. These resources can be configured to support a variety of experiments and developmental activities. Over 600 scientists and engineers perform computationally intensive tasks such as investigating nuclear optical and radar system effects, optical signature codes, and computational fluid dynamics codes.

The Edgewood Research, Development, and Engineering Center (ERDEC) maintains surety agent research facilities to support the Army's chemical and biological defense (CBD) programs. The ERDEC laboratories, equipped with security measures, fume hoods, and exhaust filtration units, perform research and product acceptance work with highly toxic materials. Analogous facilities for investigating medical countermeasures are found at the U.S. Army Medical Research Institute of Chemical Defense (USAMRICD). The Nuclear Magnetic Resonance Laboratory is the only U.S. facility certified to work with chemical surety materials. It identifies agents, degradation products, and impurities. The collocation of these facilities reduces duplication of effort and administrative costs generated by the particularly sensitive nature of the stored and handled products.

At the Communications–Electronics Command (CECOM), the RDEC has a dynamic facility that can be rapidly reconfigured to replicate existing and evolving tactical command, control, communications, and intelligence/electronic warfare (C^3I/EW) battlefield environments. The

Digital Integrated Laboratory (DIL)/testbed enables comprehensive evaluations of prototypes, evolutionary system developments, new technologies, commercial products, and systems interoperability. It interfaces with the battle laboratories supporting Advanced Technology Demonstrations (ATDs) and advanced warfighting experiments (AWEs), field sites, contractor testbeds, and simulations staffed with technical engineering experts. The DIL is a fundamental component for systems engineering and integration that focuses on battlefield intelligence, surveillance, situational awareness, combat identification, targeting, and battle damage assessment. External sites connected to the DIL include:

- Battle command battle laboratories at Fort Gordon, Georgia, and Fort Leavenworth, Kansas.
- Army battle command systems (ABCS) laboratory, Fort Monmouth.
- Joint Interoperability Test and Technology Integration Center, Fort Huachuca, Arizona.

The virtual prototyping infrastructure at the U.S. Army Tank–Automotive Research, Development, and Engineering Center (TARDEC) is revolutionizing the military ground vehicle development process. The facility demonstrates distributed virtual prototyping activities to integrate and interface advanced concepts in mobility, survivability, electronics, lethality, command and control, design, and manufacturing into any phase of a system. These activities support numerous ATDs and AWEs. The virtual prototyping facility includes :

- VEtronics simulation and integration laboratories
- Survivability Technology Laboratory
- Virtual Mockup Facility
- Software Engineering Laboratory
- Signature Laboratory
- Applied Engineering Laboratory
- Physical Simulation Laboratory
- Armor Integration Laboratory.

2. Facility Consolidation

Major S&T elements in ARL and RDEC activities are also consolidated for efficiency and to accommodate BRAC decisions. Pursuant to BRAC93, five areas of the disestablished Belvoir RDEC have been reassigned to TARDEC. About half have been relocated to Warren, Michigan. New laboratories for water purification opened in 1997.

3. Facility Modernization

Changes in technology and its application to solving Army problems make it necessary to upgrade S&T facilities.

Phase I of construction has been completed on a facility that will enable the Walter Reed Army Institute of Research (WRAIR) to vacate the substandard converted classroom building it has occupied since 1923. WRAIR will be located in a state-of-the-art facility for medical research and development missions of WRAIR and the Naval Medical Research Institute (NMRI). Planned for a staff of 850 and costing $147.3 million, the new facility will be in the Forest Glen section of the Walter Reed Army Medical Center in Silver Spring, Maryland. Locating the laboratory there allows it to be about 20 percent smaller than if it were built elsewhere.

The new building (Figure VI–4) will have a below-ground, self-contained animal facility; three floors above ground for laboratories, offices, and research activities; and a fully filtered, nonrecirculating air system. Laboratories and scientists' offices, combined with a between-floors utility distribution system, provide maximum flexibility to accommodate current and future military medical research and development.

The new laboratory's total area will be nearly 10 percent less than is currently available but that will be offset by an improved floorplan. The space per occupant and construction cost per unit

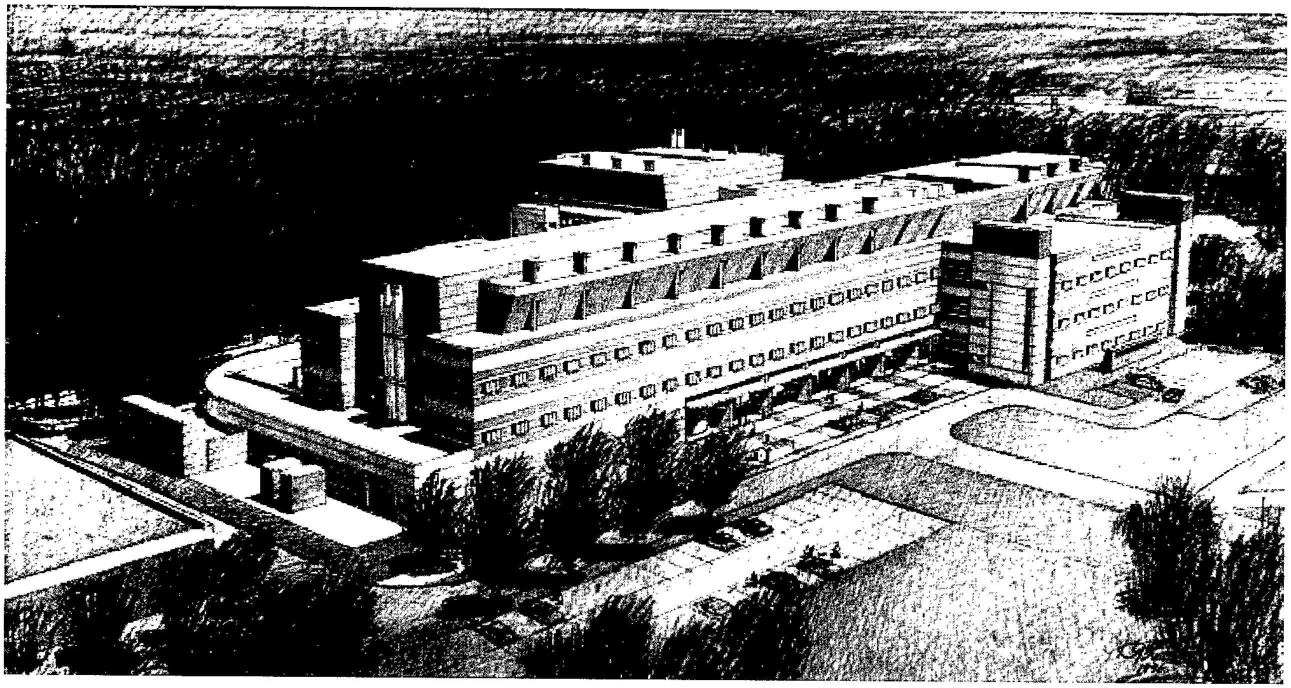


Figure VI–4. Walter Reed Army Institute of Research Facility Planned for 1999

area are below national norms. With the opening of this facility, planned for 1999, military medicine will finally have a state-of-the-art facility. It will allow WRAIR and NMRI to respond to emerging biomedical threats throughout the 21st century.

Biological containment facilities at the U.S. Army Medical Research Institute for Infectious Diseases (USAMRIID) have been renovated. USAMRIID's biosafety level 4 (BL4) laboratory is one of two maximum containment facilities in the United States. The laboratories incorporate the highest level of engineering to protect workers and prevent environmental release of extremely hazardous infectious organisms. The USAMRIID laboratories are a critical national asset and are frequently called on to support U.S. and international civilian health authorities in characterizing unknown diseases, such as Hanta virus in the southwestern United States and the Ebola virus in Africa.

A human biomechanics laboratory has been established as a joint effort between the Natick Research, Development, and Engineering Center (NRDEC) and the U.S. Army Research Institute of Environmental Medicine (USARIEM). This facility allows for world-class research concerning soldiers' strength, endurance, and load-carrying capabilities.

The trichamber altitude facility at USARIEM permits studying human performance at extremely high terrestrial altitudes. This facility has been enhanced to a fully computerized, environmentally controlled chamber, man-rated at 35,000 feet, that is capable of supporting long-term, live-in studies with complete metabolic monitoring.

Joint Precision Strike (JPS) and the Integration and Evaluation Center (IEC) at the Topographic Engineering Center (TEC) uses wide-band and tactical communications links during live and simulated exercises to support Army precision strike training, contingency planning, and survivable armed reconnaissance experimentation. The IEC provides control, data collection, environment and system simulation, and presentation/visualization support for JPS and acts as the central hub of the demonstration network. As a result of a major demonstration in the IEC, the Rapid Terrain Visualization (RTV)

Advanced Concept Technology Demonstration (ACTD) for rapid mapping and terrain visualization was developed.

4. Strategy for Facility Upgrades

Upgrading S&T facilities requires a judicious mix of renovation and new construction to ensure that the best use is made of facilities funds. As yearly plans are prepared, existing facilities are examined to determine if extensive modifications are required to carry out future plans. An early decision must be made between renovation, which takes a portion of the existing plant out of operation for a period of time, and new construction.

The review process involves a number of agencies to ensure that all factors are taken into consideration:

- Can the activity be relocated to other space available at a lower cost than new construction?
- Can the task be passed to another S&T organization that has manpower skills and space to perform the work under a cooperative memorandum of understanding?
- Can government elements outside DoD perform the work in lieu of expanding an Army facility?
- Would the effort be better performed outside the government in a federally funded research and development center (FFRDC) or industry?

The final decision within the Army rests with the laboratory director, the supporting major command, the Department of the Army staff, and, ultimately, the Secretary of the Army. There are outside reviews by DoD, the Office of Management and Budget (OMB), and Congress.

5. Shared Facilities

The Army makes extensive use of facilities controlled by other government organizations. Following are a few examples.

Facilities Shared With NASA. The Army has collaborated with NASA for 20 years in crash damage simulation, testing, and evaluation. Flight dynamics, handling qualities, and crew station design human factors are studied by NASA and Army scientists at the Ames Research Center.. The CECOM RDEC Command and Control Systems Integration Directorate and NASA have formed a Joint Research Project Office at NASA Langley, Virginia. The Army and NASA are working on controls and displays, primarily for aviation, but with applications to all platforms.

Army Collaboration With Academia. The Armaments Research, Development, and Engineering Center (ARDEC) has developed an in-house electric gun facility, the Electric Armaments Research Center (EARC) (Figure VI–5). The Institute for Advanced Technology was established at the University of Texas with a research capability in electromechanics and hypervelocity physics. The center has collaborated with facilities at the University of Texas–Austin, the EARC, and the Defense Special Weapons Agency's (DSWA)

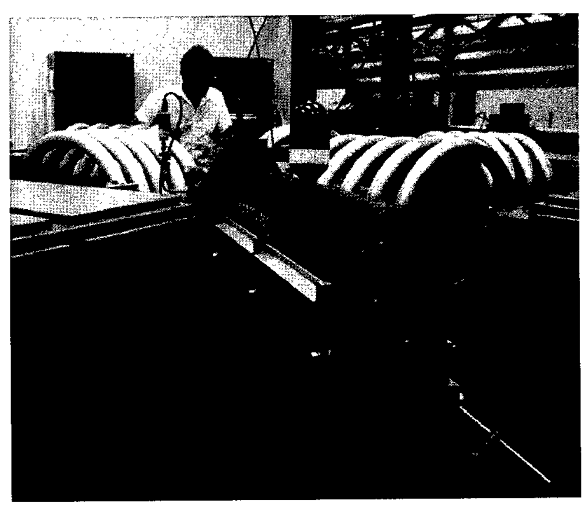


Figure VI–5. Electric Gun Concepts are Evaluated Using Unique Armament Test Facilities

Green Farm Test Facility. After laboratory tests and development, the electric gun will be range tested at the new electric gun test facility at Yuma Proving Ground (YPG).

ARL provides overall technical and contractual oversight for the Army High-Performance Computing Research Center (AHPCRC) at the University of Minnesota, with assistance from Purdue, Howard, and Jackson State universities.

The High-Energy Laser System Test Facility, managed by SMDC, is a tri-service facility with the Navy and Air Force. The sea lite beam director (SLBD) is the only one capable of transmitting a high-energy laser beam, and provides extremely high pointing and tracking accuracies for near-Earth-orbit object tracking.

6. Ranges

As environmental issues become more prominent, M&S consumes a larger portion of the S&T budget. Some range testing must precede development. One S&T range is the large blast thermal simulator being built by DSWA at White Sands Missile Range for testing combined thermal radiation and airblast nuclear weapons effects (Figure VI–6). This facility is the result of a cooperative program between the Army and the Defense Nuclear Agency (DNA). ARL recently completed a test range facility for advanced aerospace vulnerability. It is an aircraft and missile vulnerability/lethality test facility. It is particularly well suited for congressionally mandated live-fire tests of Army aircraft, missiles, and antiair weapons.

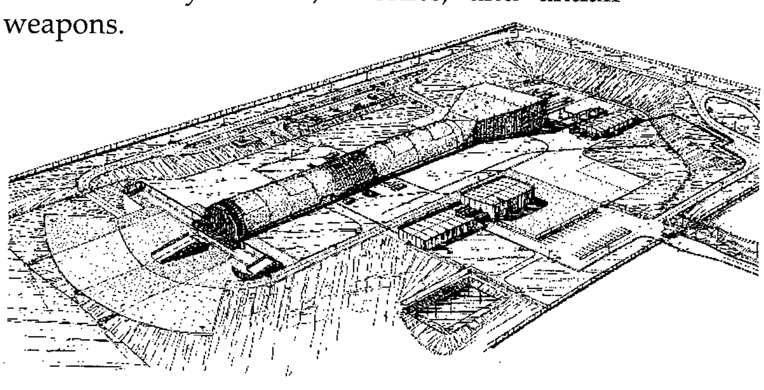


Figure VI–6. Large Blast/Thermal Simulator

Kwajalein Missile Range (KMR), Marshall Islands, Pacific, is a major range and test facility base managed by SMDC for DoD. KMR supports strategic and theater missile defense research and technology validation programs for the Army and the Ballistic Missile Defense Office (BMDO), as well as strategic offensive weapons system development and operational testing conducted by the Air Force and Navy. KMR assists in tracking and monitoring NASA space missions and provides deep-space tracking for the U.S. Space Command.

The Army Missile Optical Range at the Aviation and Missile Command (AMCOM) supports laser and laser radar measurements of selected material targets.

7. Specialized Equipment

The Army has invested substantially in sophisticated special-purpose items, such as those described below.

Several Army laboratories and centers have molecular beam epitaxy equipment to grow new semiconductor device structures with atomic dimensions. This technology applies to electro-optical sensor materials with higher resolution and greater sensitivity and signal processing devices with higher speed and greater throughput capability.

ARL's ion implantation facility (Figure VI–7) provides a state-of-the-art capability for developing and demonstrating ion surface treatments and coating techniques for Army materiel such as machine tools and parts that are subject to corrosive or high-wear environments.

ERDEC has a scanner and a laser alignment system to generate a three-dimensional (3D), digitized surface contour of a human head. Data can be transferred to a numerical control cutting machine to generate a model of a head. This is used for anthropomorphic assessments related to developing CB respirators.

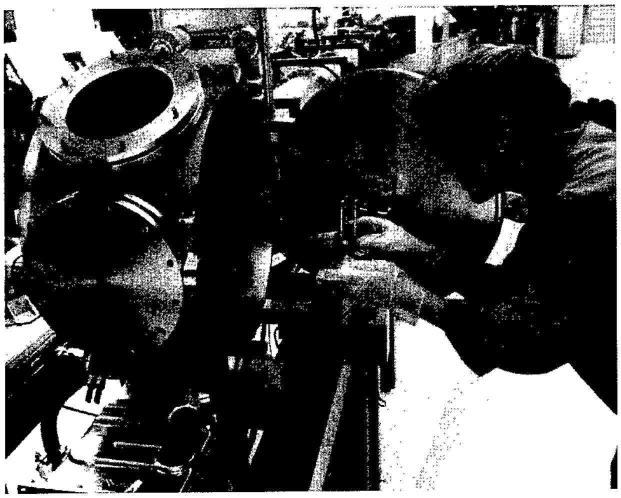


Figure VI–7. Ion Implantation Facility

C. DISTRIBUTED INTERACTIVE SIMULATION

DoD S&T strategy places strong emphasis on "synthetic environments." The distributed interactive simulation (DIS) initiative provides the lead for coordinating and integrating triservice, Defense Advanced Research Projects Agency (DARPA), and Defense Modeling and Simulation Office (DMSO) activities toward an underlying open architecture, standards, databases, and general-purpose designs necessary to achieve seamless synthetic environments. Through the DARPA-established defense simulation internet (DSI), a wide array of M&S capabilities at multiple facilities can be linked to form synthetic environments ranging in scale and resolution for a variety of uses (Figure VI–8).

Synthetic environments bring developers, scientists, engineers, manufacturers, testers, analysts, and warfighters together to address and solve their most pressing problems. Near-term efforts are using and expanding current capabilities to support S&T demonstrations and initial capabilities for Army Training and Doctrine Command (TRADOC) battle laboratories. Expe-

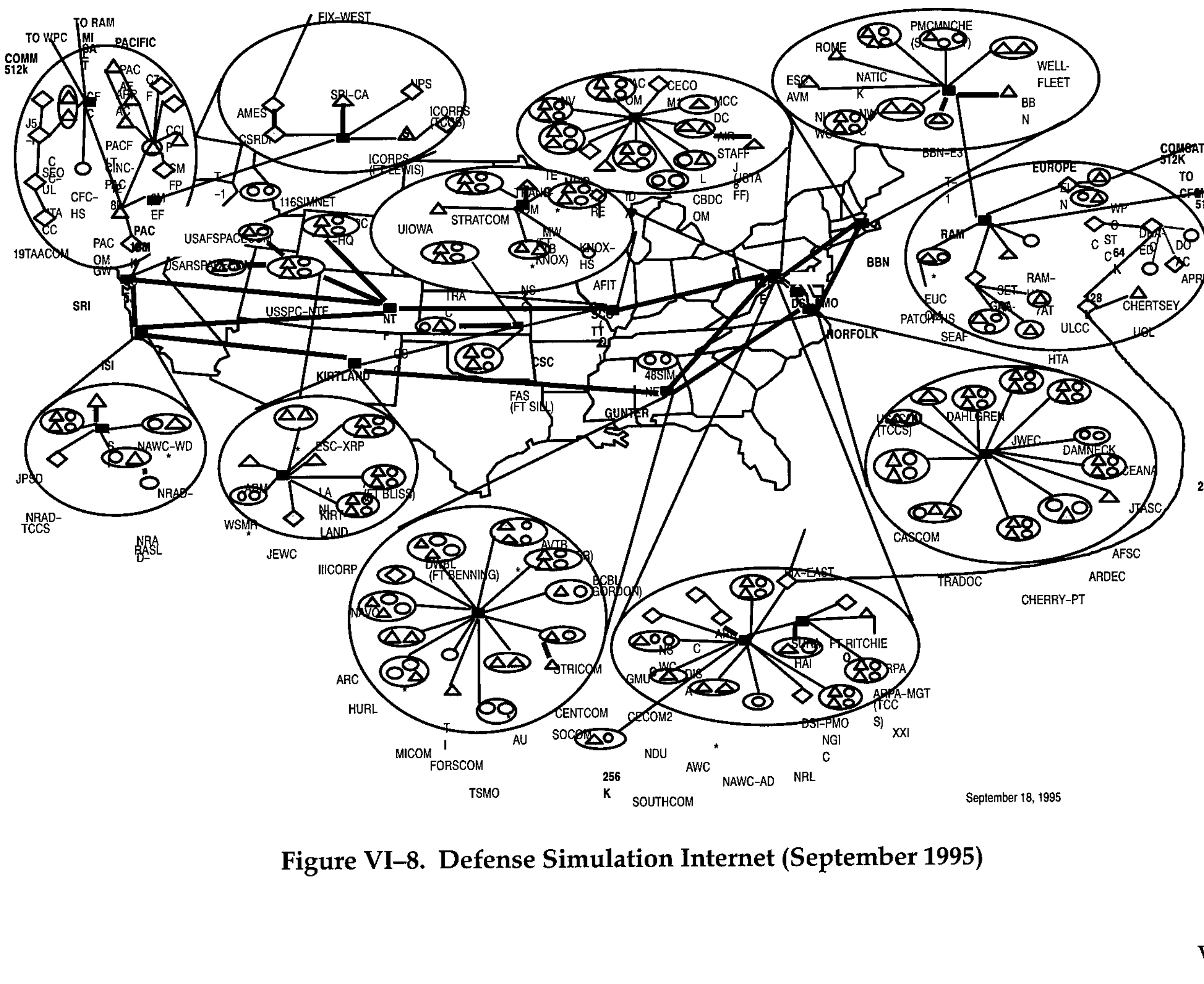


Figure VI–8. Defense Simulation Internet (September 1995)

rience gained from these activities evolve into new methodologies for evaluation and evolution of concepts and requirements in a joint task force and combined arms battlefield context with soldiers in the loop. Advances in capabilities for creating common synthetic environments are coordinated through STRICOM.

Seamless synthetic environments are achieved through the integration of simulation and modeling techniques, technology, capabilities, and processes.

Through the design and analysis of concepts in controlled synthetic environments, distributed interactive simulation offers increased savings in time and money by reducing the need for expensive mockups and field testing. Synthetic environments enhance the possibility for exploring various design options in full battlefield context, allowing workers to design and assess concepts that could not be explored using traditional approaches because of safety, environmental, and cost considerations. Distributed interactive simulation can be used Army wide to accelerate research and to permit advances in technology to be brought to the field in a timely fashion, helping to assure technological superiority on the battlefield.

1. Three Integral Components

The Defense Science Board (DSB) task force on simulation, readiness, and prototyping defines simulation as "everything except combat," with three integral components (1) live operations with real equipment in the field, (2) constructive wargames, models, analytical tools, and (3) virtual systems and troops in simulators fighting on synthetic battlefields. While the first two components are technically mature, the virtual component is evolving. Virtual capability is improving through technology advances in high-performance computing, communication, artificial intelligence, and synthetic environment realization.

The Army has adopted an electronic battlefield (EBF). The long-term objective of the EBF concept is to develop and implement a single, comprehensive environment for operational and technical simulation. The EBF is designed to support combat development, system acquisition, test and evaluation, operational test and evaluation, training, mission planning, and rehearsal in Army specific and joint operations (Figure VI–9).

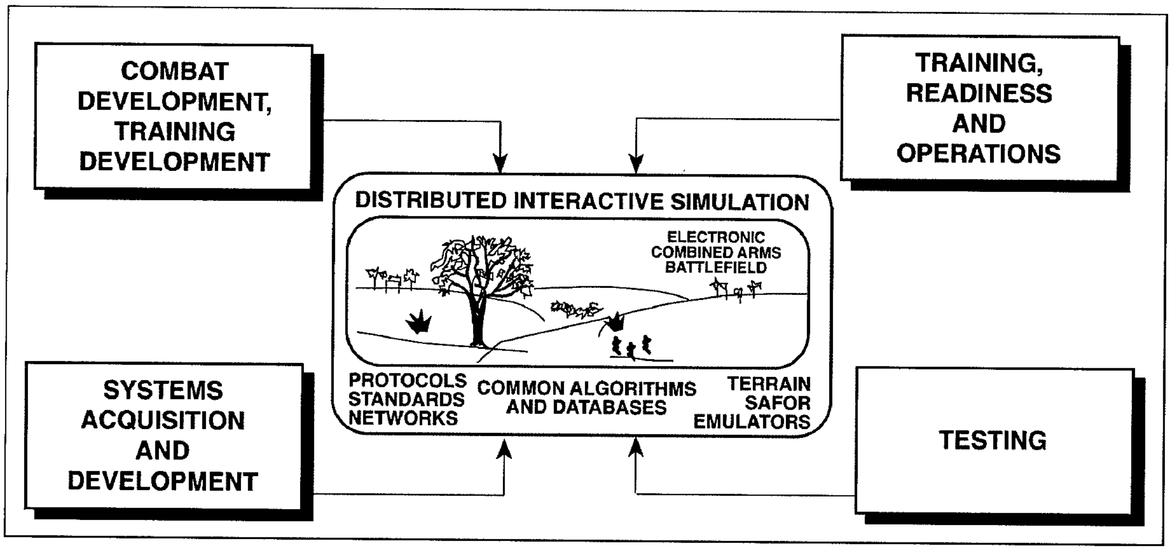


Figure VI–9. Synthetic Environment for Distributed Interactive Simulation

2. Approach

A near-term priority is the advanced distributed simulation (ADS) infrastructure to improve training and force readiness. It includes:

- High-performance computing.
- Real-time, large-scale networking.
- Data and application software methodologies for interoperability, scalability, and realism.
- Multilevel secure, hierarchical, open architecture standards, interfaces, and products.

To implement these, the Army established the TRADOC battle laboratories, the Army Model and Simulation General Officer Steering Committee (AMSGOSC) and its collateral organizations, STRICOM, Force XXI, and the Information Sciences and Technology Directorate (ISTD) within ARL.

TRADOC is the Army's DIS functional manager and is responsible for the Army-wide integration of DIS requirements, the DIS master plan, proponency for DIS verification and validation, and prioritization of the scheduling of DIS facilities.

STRICOM is the Army's technical agent for DIS technology development and network management. STRICOM activities include research, development, procurement, and support of simulators, simulations, and training devices. It also has the DoD lead responsibility for DIS-related standards and protocols and coordination with industry.

ISTD was formed to put the major battlefield information sciences and technologies under one organizational umbrella and to focus its work on the Army's operational information needs for Force XXI and beyond. This includes all M&S activities in support of the EBF.

The Army established AMSGOSC to oversee DIS and other M&S-related activities from a corporate perspective. It is cochaired by the Vice Chief of Staff of the Army and the Assistant Secretary of the Army (Research, Development, and Acquisition), who also cochair the Army Science and Technology Advisory Group. An expanded Army Modeling and Simulation Executive Committee, cochaired by the Deputy Under Secretary of the Army (Operations Research) and the Deputy Chief of Staff for Operations and Plans, provides overall management and has established three groups—the Advanced Simulations Working Group, the Requirements Generation Working Group, and the AMS Management Plan Working Group. The working groups are chaired by the AMS Office, which is charged with developing an integrated investment strategy across the three domains encompassed by the EBF: (1) advanced concepts and requirements (ACRs), (2) RDA, and (3) training, exercises, and military operations (TEMO) (Figure VI–10). Each has a domain manager at the Department of the Army Headquarters level, and a domain agent at the major command level (TRADOC for ACR and TEMO, AMC for RDA). Management and investment plans are prepared for each domain.

The DIS master plan describes the program currently in place, the envisioned future capabilities, and the plan to achieve these objectives. The Army established a two-pronged investment strategy for DIS to support Army training and acquisition (Figure VI–11). The combined arms tactical trainer (CATT) (Figure VI–12) and the battlefield distributed simulation–developmental (BDS–D) (Figure VI–13) are directed to provide real-time, man-in-the-loop, synthetic environment simulation capabilities as follows:

- Link combat systems, wargame simulations, and manned simulators into a hybrid real/virtual battlefield environment.
- Provide an open-ended hierarchical architecture with DoD common standards and protocols.
- Provide a realistic behavioral representation of the battlefield at each echelon.
- Orchestrate a large-scale distributed networking of resources.

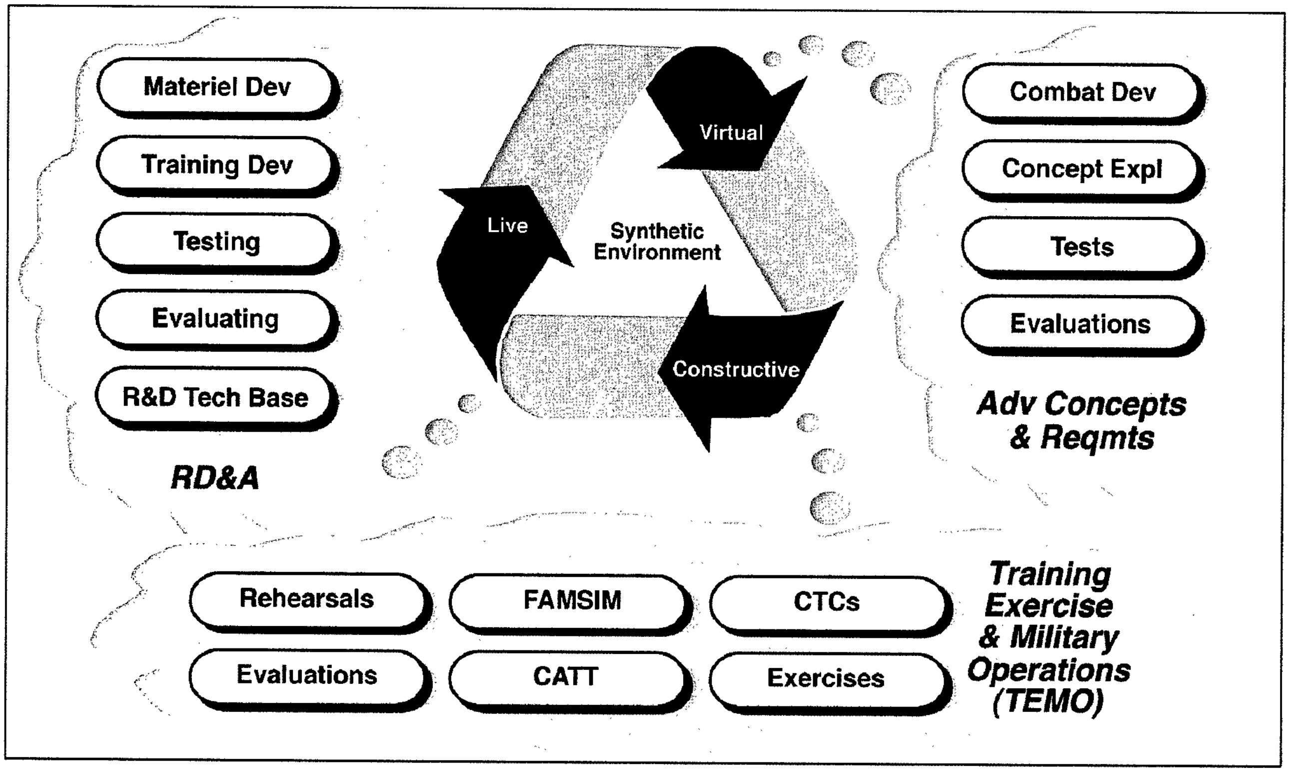


Figure VI–10. DIS Synthetic Environment. A time- and space-coherent representation of a battlefield environment measured in terms of human perception and behavior of those interacting in the environment.

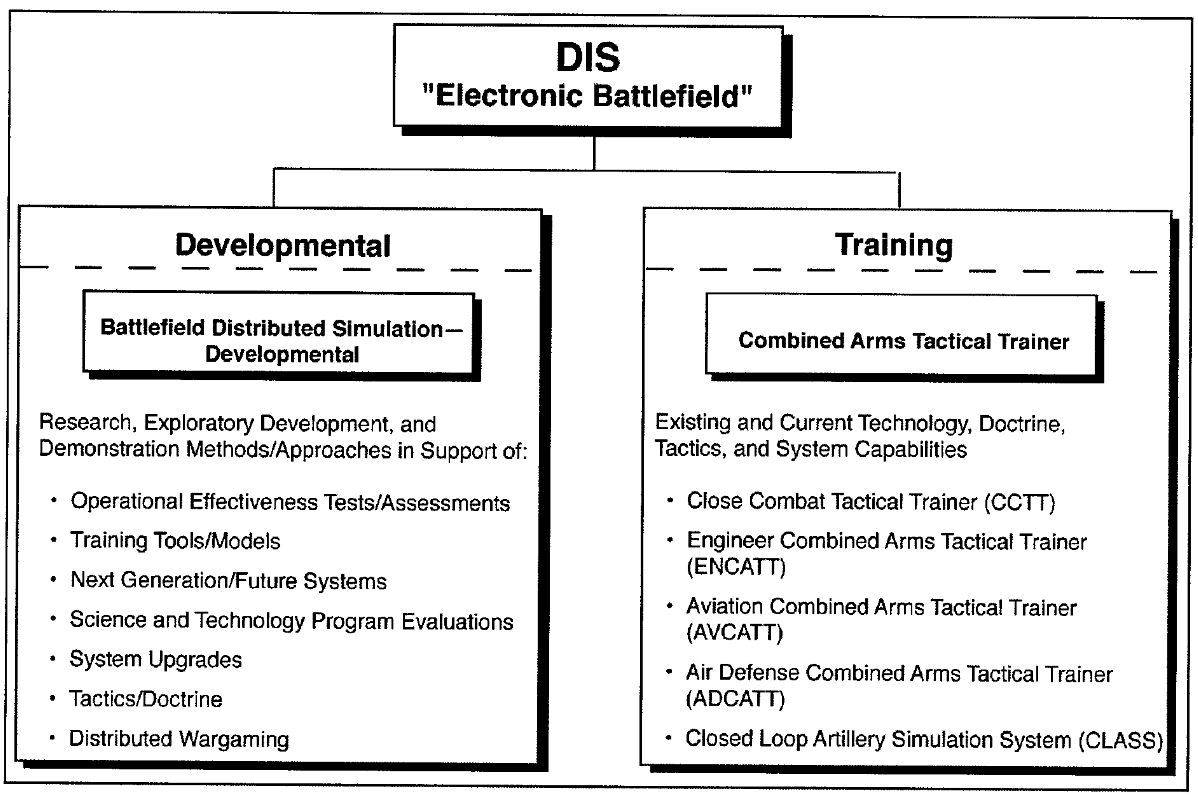


Figure VI–11. DIS Electronic Battlefield

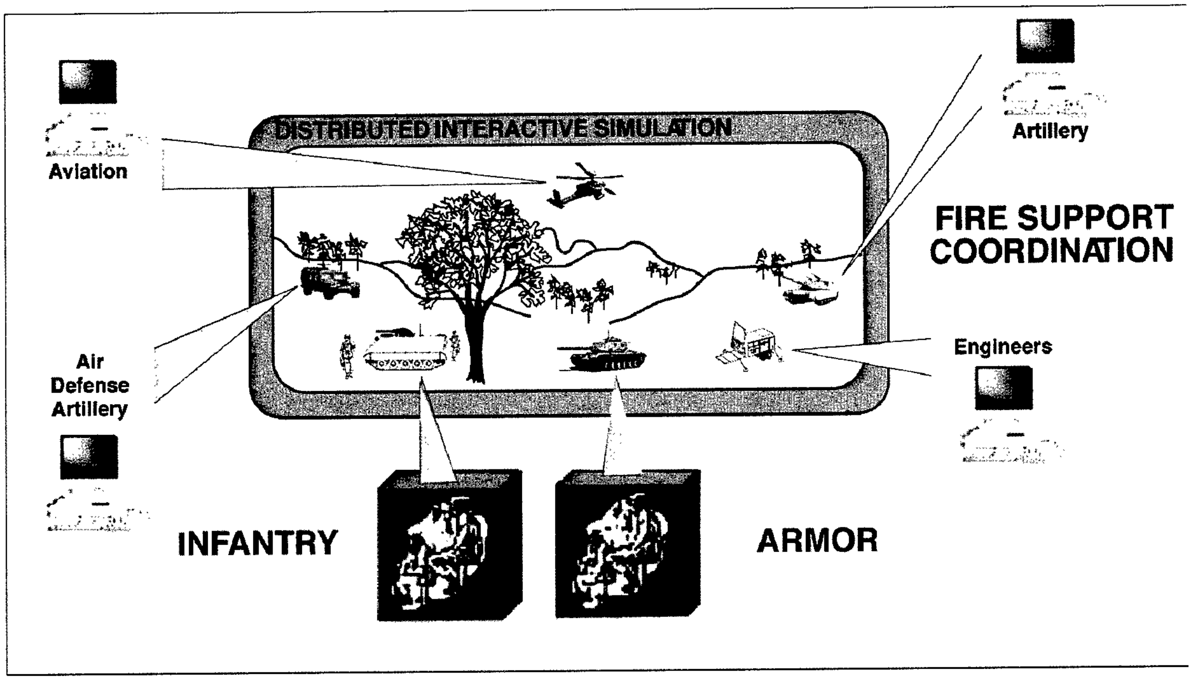


Figure VI–12. Close Combat Tactical Trainer

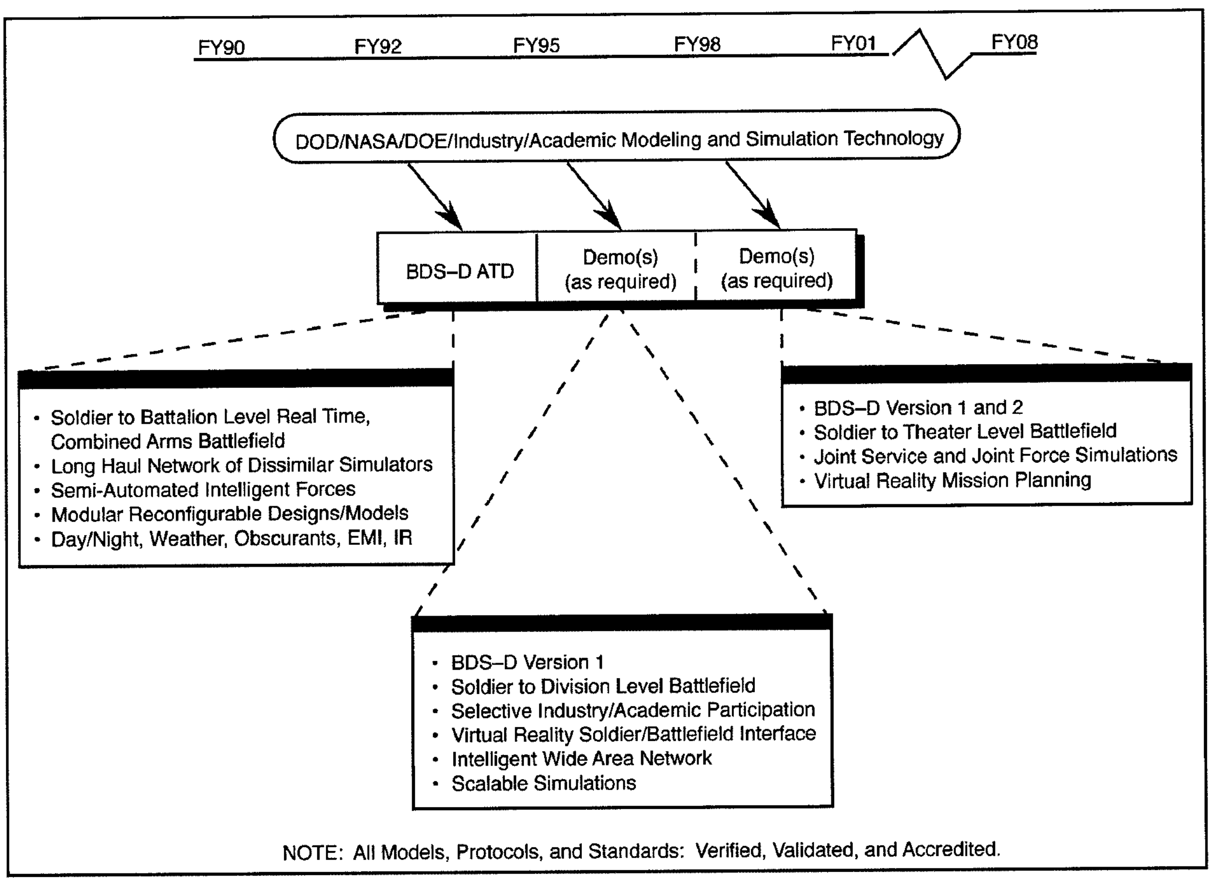


Figure VI–13. BDS–D Program

The CATT focuses on integrating existing systems, tactics, and doctrine into a combined arms training environment from vehicle crew through battalion task force. BDS–D is directed toward future systems and concepts and encompasses all phases of materiel, combat and training developments, and testing. Initial operational capability for CATT is planned for 1999.

The BDS–D program is developing a distributed simulation capability linking government, university, and industry sites into an accredited, real-time, warfighter-in-the-loop simulation of the joint and combined battlefield. Manned simulators on the network embody the operational characteristics of the systems they represent. The BDS–D includes an evolutionary process and strategy to systematically develop, maintain, and use technologies and associated hardware and software to achieve the long-term objective of EBF (Figure VI–13). This program continually exploits the advances from our national ADS S&T developments. The Army ADS S&T program is focused on technology development for:

- Army-specific requirements to ensure their timely availability to be placed in the BDS–D process and other simulation applications.
- The electronic battlefield of tomorrow, where advanced, interoperable, distributed simulations—live, constructive, virtual—at geographically separated locations are connected to cooperatively form highly realistic synthetic environments.

The DSI (Figure VI–8 above) will be the connecting linkage and provide the high-level connectivity necessary to accomplish R&D and training goals.

D. MODELING/SOFTWARE/TESTBEDS

Advances in computer technology have allowed Army engineers and scientists to make increasing use of models and simulations and save money. When hardware procurement is eliminated because the needed information can be obtained through simulation, both time and money are saved. In addition, environmental impacts such as noise and pollutants generated during physical trial and error evaluation are eliminated. The following sections discuss computer M&S, software technology, physical simulation, hardware-in-the-loop simulation, combined arms battlefield soldier-in-the-loop simulation, and T&E simulation.

1. Computer Modeling and Simulation

Computer M&S can generate images of complex data and evaluate experimental conditions and approaches. Visualization techniques used with complex modeling permit scientists and engineers to exploit new concepts without the development of costly prototypes. Computer M&S is applicable to a wide range of technical disciplines as illustrated below.

Human Factors Modeling. ARL's human performance model program uses JACK, a 3D model developed by the University of Pennsylvania (Figure VI–14). JACK is used in the Aviation RDEC's A31 (Army–NASA Aircrew/Aircraft Integration) program aimed at producing software tools and methods to improve the human engineering design process for advanced technology crew stations. This approach allows

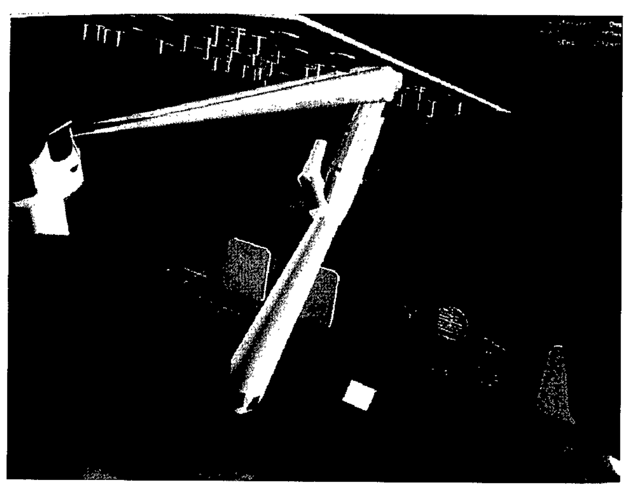
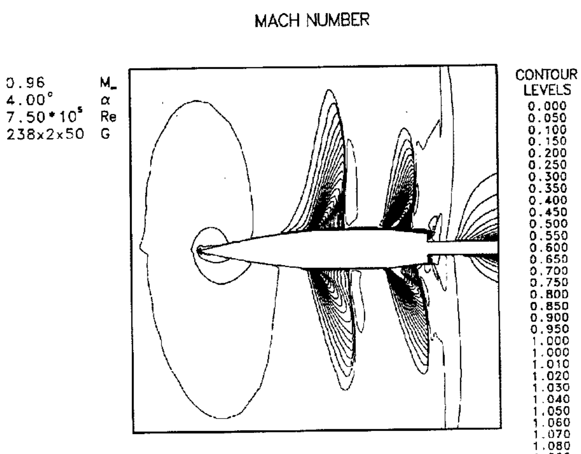


Figure VI–14. JACK. JACK, a 3D computer-aided design human figure model, is used to evaluate soldier interactions with weapon system design concepts.

variations of mission procedures and cockpit equipment to be explored rapidly prior to committing a design to an expensive hardware simulator.

Armor and Projectile Modeling. High-speed, large memory supercomputers have greatly enhanced our capabilities in modeling new armor concepts and advanced projectile technology. Recent large-scale simulations have provided insight into the potential benefits of advanced high-velocity projectiles. Figure VI–15 illustrates one penetrator concept. The penetrator is composed of a train of segments supported in a carrier tube. The train-of-segments model is a laboratory version of a segmented projectile that may have merit for use in future armor systems.

Experimental Projectile Flight



Simulated Projectile Flight

Figure VI–15. Computer Simulations. Computer simulations of device design and operation can be used instead of costly prototyping and field tests. The comparison shows the accuracy with which computer simulations can reflect the physical world.

Environmental Modeling. Army tactical operations must take into account their environments. Digital terrain information and atmospheric information are used in wargames and simulations to determine the outcome of tactics changes and new equipment introductions. Climate databases provide realism by projecting different weather conditions into a simulated theater of operations. Weapon systems are evaluated for effectiveness, taking into consideration target detection probabilities based on climate and terrain masking.

Weapons and Fire Control Modeling. ARDEC at Picatinny Arsenal, New Jersey, has established a DIS node to determine and show how technology, weapons, and weapon mixes can be used to maximize the effectiveness of the soldier.

2. Software Technology

DARPA is the sponsor of the Software Technology for Adaptable, Reliable Systems (STARS) program to increase software productivity, reliability, and quality through the adoption of a new software engineering paradigm called megaprogramming.

STARS is sponsoring megaprogramming demonstration projects on DoD systems within each of the services. These demonstration projects help quantify the benefits of the megaprogramming paradigm and the issues involved in transitioning to this new paradigm.

The Communications–Electronics Research, Development, and Engineering Center (CERDEC) has developed the STARS Laboratory to support the development of domain models and architectures and reusable assets. The software engineering environment is also used to reengineer C^4I weapon system software to include the integration of domain architectures and assets in the application software.

3. Physical Simulation

Physical simulations are used today in Army research to emulate real-time physical motions of active systems in the field. In many situations, computer-generated models and simulation systems can interact with physical simulations to greatly reduce the need for costly and time-consuming field tests of prototypes. Following are examples of advanced physical simulation facilities operated with computer-generated models or simulation systems.

The crew station/turret motion base simulator (CS/TMBS) is a full six-degrees-of-freedom (DOF) laboratory simulator with high-performance capabilities. It can impart a maximum of 6 g acceleration to a heavy combat vehicle turret weighing up to 25 tons and replicate, via computer control, motions/vibrations that would be encountered while traveling over rough cross-country terrain. This simulator at TARDEC is man-rated and approved for occupancy by a crew. The CS/TMBS plays an important role in turret system development, characterization, and virtual prototyping activities in a variety of combat vehicle programs. The operation of different azimuth drive motors in a Bradley fighting vehicle turret is shown in Figure VI–16.

Among the advantages of man-in-the-loop tests in the laboratory are close control of parameters and exact repeatability of tests for comparing the effect of different components.

The Aviation RDEC Crew-Station Research and Development Facility (CSRDF) supports the evaluation of new concepts for human–system interactions for advanced rotorcraft. Effects of malfunctions, automation alternatives, and mission equipment tradeoffs can be conducted in this synthetic environment of 3D visuals, sounds, and tactile stimuli (Figure VI–17). The degree of realism achieved in such systems can best be appreciated by seeing a pilot emerge from a laboratory "flight" showing perspiration and other signs of stress. The CSRDF is used extensively to support

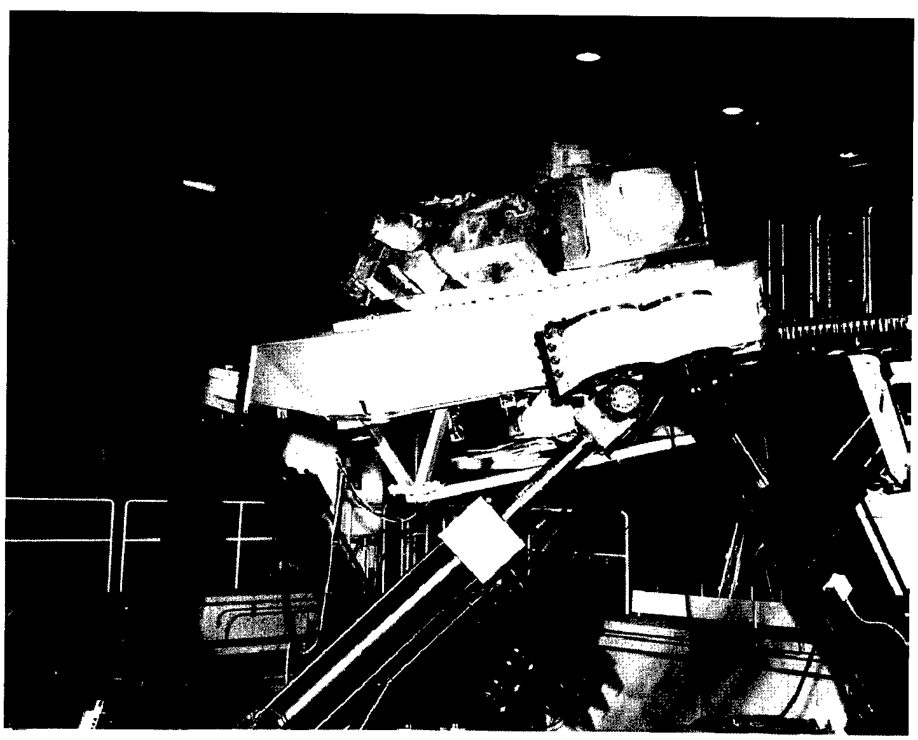


Figure VI–16. Crew Station/Turret Motion Base Simulation. The CS/TMBS allows new vehicle turret designs to experience real-world operational environments in a controlled laboratory setting.

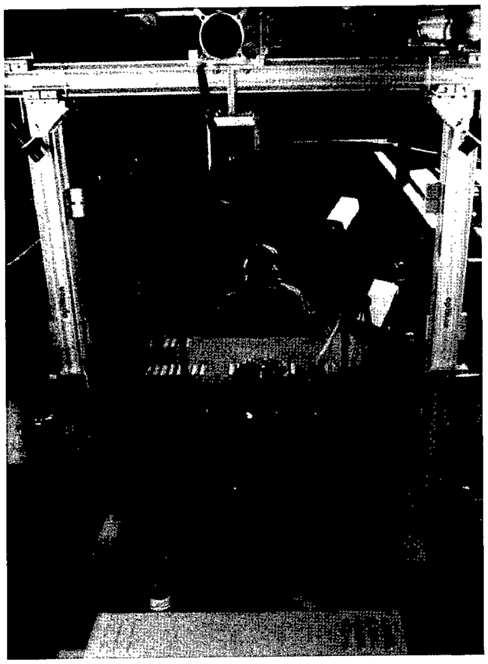


Figure VI–17. Rotorcraft Simulator Facility. Innovative rotorcraft technologies are evaluated for operational compatibility in the rotorcraft simulator facility.

the Rotorcraft Pilot's Associate ATD and is one of the primary simulators used to validate DIS protocols and the BDS–D program. The aviation testbed at Fort Rucker and the CSRDF have been linked to support Force XXI objectives and are being extended to include Tank–Automotive and Armaments Command (TACOM), line-of-sight antitank (LOSAT), and Sikorsky Comanche simulators.

Another example is the simulator training advanced testbed for aviation (STRATA). Through a cooperative agreement with the Government of Canada, the Army Research Institute (ARI) developed the STRATA research simulator to examine the full range of training device and flight simulator training strategies and tradeoffs and design requirements for future low-cost simulators. STRATA is a dedicated research facility at ARI's Fort Rucker field unit for aviation training research. STRATA permits rapid reconfiguration to emulate training devices with different visual displays, cockpit configurations, aerodynamic models, etc. STRATA will enable the Army to empirically determine the most effective training strategies using an affordable mix of live exercises and existing training aids, devices, simulations, and simulators for initial flight skills.

CECOM's Night Vision and Electronic Sensors Directorate has developed a facility to support the development and testing of integrated aircraft and ground vehicle sensors and countermeasures. The multispectral environmental generator and chamber (MSEG&C) provides 360-degree radar frequency, laser, infrared, and ultraviolet simulation of air defense radars, surface-to-air missiles (SAMs), top-attack/smart munitions, and laser threats. Varied individual and integrated protection equipment is used to simulate ground vehicle and aircraft attitudes. The equipment is instrumented and placed on a computer-controlled table in the center of an anechoic chamber (Figure VI–18).

Figure VI–18. Multispectral Environmental Generator and Chamber

4. Hardware-in-the-Loop Simulation

Hardware-in-the-loop simulations test types of systems using real hardware and computer simulations, providing a significant return on investment for the Army.

One example of hardware-in-the-loop simulation is ARDEC's Ware Simulation Center located at Rock Island Arsenal, Illinois (Fig-

ure VI–19). This simulator provides a realistic emulation of the field environment that an armament system will encounter. The facility can test weapons using up to 30-mm live or 40-mm inert ammunition. In addition, the facility's 6-DOF simulator is a large mount capable of holding weapons, gun turrets, and vehicle sections weighing up to 10,000 pounds. Programmed vibrations as well as pitch and yaw motions may be applied to the attached loads while the weapons are test fired in the indoor range.

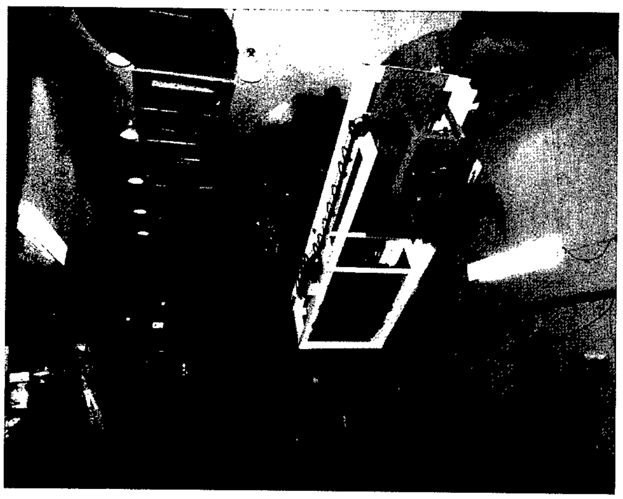


Figure VI–19. ARDEC's Ware Simulation Center. The center's 6-DOF mount allows conceptual and fielded weapons to be fired in realistic mounting environments to isolate design deficiencies in controlled laboratory conditions.

The AMCOM open-loop tracking complex (OLTC), a computer-automated electro-optical countermeasure (EOCM) simulation facility, provides electronic warfare analysts the tools for evaluating the performance and effectiveness of EO air defense missile systems and guidance assembly hardware in the presence of countermeasures.

CECOM has implemented the Army Interoperability Network (AIN), a nationwide suite of distributed communications capabilities and services to support interoperability and software development for Army C^4I systems throughout their life cycle. The AIN provides the Army infrastructure for C^4I systems to achieve the objectives of the Army Enterprise Strategy (i.e., battlefield digitization and C^4I for the warrior). The AIN provides rapid engineering support solutions that replicate battlefield configurations by networking dispersed fielded C^4I systems. Current AIN major operational equipment includes the AIN Central Control Facility, Protocol Assessment Facility, four sites at Fort Monmouth, and remote sites at Fort Leavenworth, Fort Sill, and Fort Huachuca. A remote site is planned for PEO Armored Systems Modernization at General Dynamics Land Systems, Warren, Michigan. A transportable AIN node is available to provide quick-reaction AIN access in situations requiring rapid test support. The AIN is the Army's infrastructure for linking the battle laboratories with the RDECs.

5. Combined Arms Battlefield Soldier-in-the-Loop Simulation

Enhanced design architectures and improved battlefield simulation techniques are rapidly growing areas of Army simulation and modeling capability. The Army leadership has a vision of how the totality of battlefield simulation technology and techniques can be used throughout the research and acquisition process (Figure VI–20).

The cornerstone is the BDS–D program, designed to create and maintain a distributed, state-of-the-art network capability linking government, university, and industry sites into a simulation of the combined and joint arms battlefield. The BDS–D program is shown in Figure VI–11 above.

Using current and emerging long-haul data communication capabilities to create wide area networks (WANs), simulation capabilities will be resident at geographically separate sites and linked together to form much larger synchronized simulation environments. Thus simulation environment can be "packaged" in sizes and places corresponding to the size and location of actual units for evaluating weapon system, force development, and training concepts (Figures VI–21 and VI–22).

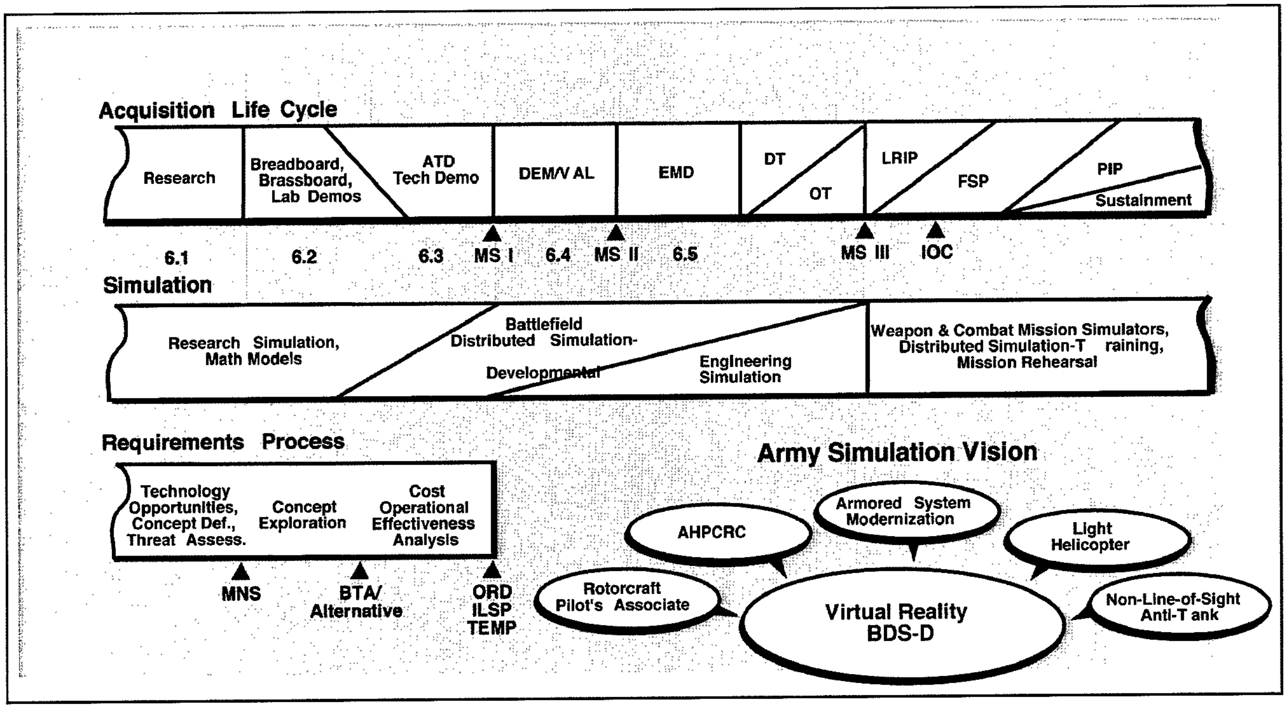


Figure VI–20. Potential Use of Battlefield Simulations Throughout the Research and Acquisition Process

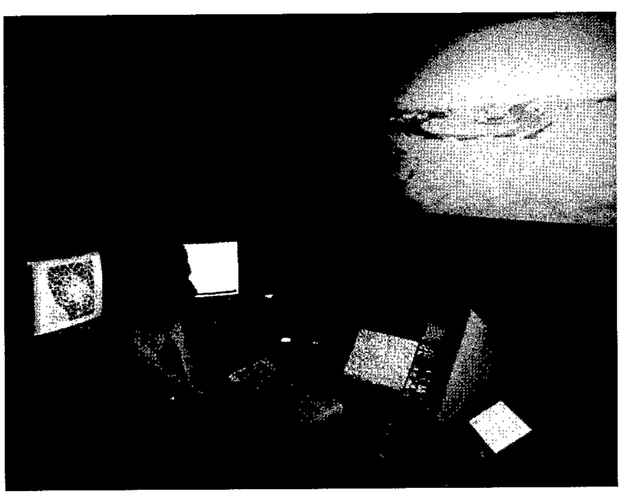


Figure VI–21. BDS–D Referees. With BDS–D, war-game exercise referees can observe training operations from any vantage point on the battlefield while remaining transparent to the players.

Figure VI–22. BDS–D Training. BDS–D will give weapon system operators the ability to more realistically train with non-line-of-sight missile technologies.

Armored Systems Modernization (ASM) is similarly being analyzed under the BDS–D concept. ASM mobility, weapon station stability, and ride quality, as well as the survivability of all the ASM variants, will be evaluated in a true combined arms simulation. Anticipated ASM capabilities are being simulated and evaluated via the BDS–D test bed resources; crew controls and displays for the LOSAT variant of the ASM family have been prototyped within the BDS–D resources and successfully used to describe valuable human factors modifications.

6. Test and Evaluation Simulation

Technological progress must be complemented by test and instrumentation facilities, including T&E simulation, that can measure the technological progress being achieved. Environmental and safety concerns increasingly impose constraints on T&E facilities. The ability to simulate the physical conditions of the battlefield for T&E reduces the time to obtain data and cost. Bringing the test environment under laboratory control provides high-quality, reproducible data that can be recorded and analyzed during the test process.

E. INFORMATION TECHNOLOGY/ COMMUNICATIONS

To speed information transfer within the S&T community, substantial improvements have been made in the supporting communications infrastructure. The explosive growth of microcomputers, software applications, and networking has permitted more effective use of information in the management of S&T. Reengineering of workflows will occur as information is shared concurrently among organizations so that products are speedily delivered with higher quality.

F. PERSONNEL

Approximately 22,000 in-house personnel support the Army R&D mission. Working with a diversified set of physical resources that range from solid-state physics laboratories to outdoor experimental ranges, these personnel conduct research, technology, and product support activities for the total Army in medicine, the life sciences, psychology, physics, engineering, and numerous other fields of science. Microelectronics, fluidics, and digital computing are only three major examples of technologies in which major advances have sprung from Army in-house organizations.

To enhance management of the acquisition fruits of the S&T process, an Army Acquisition Corps has been established, composed of career professionals. Persons committed to this specialized career field are offered significant educational opportunities to enhance their professionalism.

Demographic projections for college graduates indicate a declining number of engineers and scientists. To address this national issue, the Army is developing a comprehensive set of policies and plans to recruit, train, and retain scientists and engineers. These policies include the selective use of demonstration programs to enhance recruitment, the proper use of long-term fellowships for graduate degrees, and the placement of individuals in laboratories for hands-on work assignments. Retention is a major issue since technical personnel often leave for the higher salaries paid by industry and academia. The experimental use of wider pay bands, special pay, and other OSD and Army initiatives are being studied to remedy this problem.

In response to the April 1994 findings of the DSB Task Force on Laboratory Management, five Army laboratories were selected for Phase I implementation of an Army S&T personnel demonstration. Five separate proposals have been approved by the Army, OSD for Civilian Personnel Management, and the Office of Personnel Management. Organizations involved in the demonstration include ARL, Missile Command Research and Development Center, the Aviation Command Research and Development Center, the Medical Research and Material Command, and the Waterways Experiment Station. Implementation of the demonstrations began in Octo-

ber 1997. Nearly 9,000 people are involved in the five pilot projects.

These demonstrations are the first major changes to improve the personnel systems specifically tailored to the Army laboratories. Waivers were submitted to Title V law in hiring flexibility, broadbanding and classification, pay for performance, automated job classification, and expanded developmental opportunities. These changes to Title V as well as to DoD and Department of the Army personnel policies will allow the Army laboratories greater flexibility and authorities to manage and improve staffs. The demonstrations go far in answering criticisms from the DSB and others that he current system is too slow, puts up administrative barriers, and is impossible to change.

* * *

As illustrated in this chapter, the Army is investing in its supporting infrastructure to maintain world-class S&T capabilities that will meet future Army needs. The Army will continue to use leveraging strategies wherever possible to interface effectively with other governmental bodies, industry, and academia.

Simulation investments discussed in previous editions of this plan are emerging at just the right time to support the needs of planners and operators faced with a base-deployed, downsized Army. This investment is meeting the needs of the TRADOC battle laboratories for planning the Army of the future and providing the materiel developers with the tools to demonstrate new technologies and operating capabilities in a more cost-effective way than has heretofore been available.

CHAPTER VII

TECHNOLOGY TRANSFER

CONTENTS

CHAPTER VII

TECHNOLOGY TRANSFER

Today's modernization is tomorrow's readiness: without it, we risk sending soldiers into the next war without the technological edge required to obtain decisive victory with minimum casualties.

General Dennis J. Reimer
Army Chief of Staff

A. ARMY TECHNOLOGY TRANSFER

The Army technology transfer program seeks to promote the transfer of technology to enhance both the economic competitiveness of our country and our military capabilities. Army laboratories and centers have a wealth of technology, advanced facilities, and expertise that can be used for more than national defense. The Army technology transfer program works in synergy with our national industrial infrastructure to strengthen both military and economic security. This military–commercial synergy has always been important, but as military resources decrease with the end of the cold war and as commercial competition replaces military competition, it becomes critical.

Once the Army sustained a technology and production base that was focused on military needs and isolated by culture and rules from the civilian commercial world. The Army is no longer able to afford this luxury. In fact, ending this isolation in some technical areas will enable the Army to exploit commercial technology that is more advanced than its military counterpart. The Army continuously monitors new developments in the commercial sector, looking for potential military applications.

In the 1980s, formal technology transfer programs were initiated to apply spin-off from military technology to benefit the civilian economy. But with the decline of defense funding, changes in the nature of the military threat, and an increase in the rate of change of commercial technology development, DoD's emphasis has evolved to include dual-use and spin-on technology. Dual-use technologies have both defense and nondefense applications. Spin-on technologies are developed outside the Army, but have military applications. The potential to bolster civil and military strength through a common production base is being recognized in DoD and technology transfer is now recognized as essential to DoD's mission.

This chapter describes various components of the Army technology transfer program, which uses an exceptionally wide range of management approaches, legal mechanisms, and types of partners.

B. DUAL-USE TECHNOLOGY—NATIONAL DEFENSE AND ECONOMIC COMPETITIVENESS

As defense spending declines, we must merge military and civilian technology and production bases wherever possible. Because dual-use technologies have both defense and nondefense applications, our military capability gains from the large investment in civilian R&D and production capacity; conversely, our economic capability gains from military investment (usually in leading-edge technology). Similarly, med-

ical and environmental capabilities developed for the military have civilian application, and vice versa. Therefore significant effort is devoted to tailoring our R&D programs so we do not reinvent the wheel in areas where civilian capability leads, but effectively hand off our advances where they have value to the civilian economy.

This section highlights several programs that are designed to encourage development of dual-use capabilities, and to hand off those aspects of predominantly military capabilities (technologies, know-how, and facilities) that have civilian application.

1. Small Business Innovation Research Program

The Small Business Innovation Research (SBIR) program allows the Army to access the innovative technologies of small, high-technology firms. Using a competitive selection process, the Army SBIR program supports small high-technology businesses in conducting high quality research on innovative concepts. Of particular interest are R&D efforts leading to solutions of Army defense-related scientific or engineering problems that permit the small businesses to commercialize their developed technologies in the private sector.

As mandated by public law, the SBIR program is intended to (1) stimulate technological innovation, (2) increase small business participation in federal R&D, (3) increase private sector commercialization of technology developed through federal R&D, and (4) foster and encourage participation in federal R&D by women-owned and socially and economically disadvantaged small businesses. Firms participating in SBIR must employ fewer than 500 employees, as defined by the Small Business Administration and must be U.S.-based, for-profit businesses.

Congressional mandate requires that all federal agencies having an annual extramural R&D budget exceeding $1 billion must participate in the SBIR program. The SBIR budget is computed according to a certain percentage of the participant's extramural R&D budget. For FY97 and thereafter, this percentage is 2.5 percent. The Army SBIR budget for FY97 was $93.7 million and is expected to remain at that level for FY98.

Each year, in cooperation with other DoD components, the Army generates and publishes a set of high-priority topics in the SBIR solicitation and invites small businesses to submit proposals dealing with these topics. The SBIR solicitation lists the topic opportunities, defines proposal formats, and states the proposal evaluation and selection criteria.

The SBIR program is a three-phase program as depicted in Figure VII–1. Phase I determines the scientific or technical merit and feasibility of proposed concepts and typically takes up to 6 months to complete. Approximately 1 in 10 to 1 in 5 Phase I proposals are selected for award. Those Phase I performers showing the best promise may be invited by the Army to submit Phase II proposals. Phase II is a 2-year effort covering the main R&D work. Approximately one-third to one-half of the invited Phase II proposals are selected for award. Phase II projects develop well-defined products or services that have relevance to the Army/DoD and the private sector.

Phase III is the last step in the SBIR process. In Phase III the small business is expected to market and sell the products or services outside the SBIR program that were developed during Phase I and Phase II. No SBIR funding is provided in Phase III; however, the firm is free to pursue non-SBIR government follow-on contracts (sole-source or

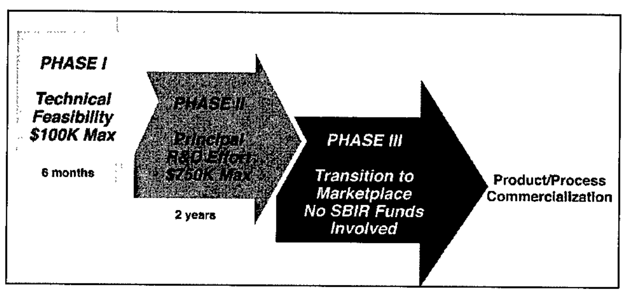


Figure VII–1. Small Business Innovation Research Program Flow Process

otherwise), or a leveraged combination of non-SBIR government and private sector funding.

Since 1982, the Army SBIR program has funded thousands of small businesses working to provide innovative dual-use technologies. The program has been successful in meeting or augmenting Army technology needs while strengthening the nation's small businesses by moving their technologies to the marketplace. This process was greatly enhanced, beginning in FY96 and continuing through FY97, by the Army's implementation of the SBIR 2-year pilot fast-track program. This program was designed to accelerate into Phase III those small businesses that are able to identify third-party matching funds for Phases I and II. The Army also implemented acquisition streamlining procedures during calendar year 1996 in its Phase I and II selection and award processes. These streamlining procedures have shortened FY97 Phase I and Phase II selection/award times to an average of 4 months and 6 months, respectively.

The Army promotes the commercialization goal of SBIR by conducting an annual Phase II Quality Awards Program that recognizes stellar Army Phase II projects for their technical achievement, contribution to the Army mission, and commercialization potential. A panel of Army and industry experts selects five projects each year to receive this award. The winning companies and their sponsoring laboratories or centers are presented with the awards at an annual awards banquet. Throughout the year, the winners and their accomplishments are showcased at several Army conferences and symposia.

During 1996, an operating and support cost reduction (OSCR) initiative was implemented to target a segment of SBIR efforts at this critical high-payoff area. Initially, the goal was to have at least 15 percent of the 1996 SBIR solicitation topics directed at OSCR issues. Due to the responses of the laboratories, centers, and small business community, this goal was surpassed for topics (20 percent) and at each subsequent stage of the SBIR process. Of the Phase I awards, 20 percent were to OSCR projects. These OSCR Phase I projects will compete for Phase II funding in FY 1998.

Information about the Army SBIR program is available via the Internet at the following Website address:

http://www.acq.osd.mil/sadbu/sbir

2. Small Business Technology Transfer Program

The Small Business Technology Transfer (STTR) program began in FY94 as a 3-year pilot program established by Congress in P.L. 102–564, the Small Business Research and Development Act. The STTR program was reauthorized for FY97 and reauthorization for the period FY98–00 is under consideration by Congress. The STTR program is a competitive program that urges small businesses to partner with researchers at universities, nonprofit research institutions, or federally funded R&D centers (FFRDCs) to speed commercialization of emerging technologies and discoveries of interest to the Army and the private sector. The small business must perform a minimum of 40 percent of the R&D work in STTR contracts and must subcontract with a research institution for a minimum of 30 percent of the proposed work.

Army STTR topics are based on critical technologies that reflect the Army mission and emphasize potential commercialization and dual-use applications. The Army had 12 topics in the FY97 DoD STTR solicitation, which closed on 2 April 1997. The FY97 Army STTR budget is derived from a set-aside of 0.15 percent of the total FY97 Army extramural R&D budget.

Similar to the SBIR program, the STTR program consists of three phases. Phases I and II are funded with Army STTR funds. Phase I, the proof-of-principle phase, is limited to $100,000 and 1 year. Upon satisfactory performance during Phase I, selected small businesses are invited to submit Phase II proposals. Phase II awards are limited to $500,000 over a 2-year period. Phase III is the commercialization phase, wherein the

small businesses transfer the matured product or technology to the market. The small businesses receive no STTR program funding for Phase III.

The first "graduates" of the STTR program will complete Phase II this year and enter Phase III. Some firms have already received commercial contracts for their STTR-developed products. Successful Phase III transition of these firms to the commercial marketplace will be highlighted in future Army publications.

Extensive STTR program information is available via the Internet at the Web address listed above.

3. Army Domestic Technology Transfer Program

The Army Domestic Technology Transfer (ADTT) program seeks to create an environment that fosters and facilitates the transfer of technology between military and civilian applications, thereby contributing to military needs and economic competitiveness. There is a long history of technology transfer from in-house Army R&D to commercial application. For example, Army technologies form the basis for both the alkaline battery industry and the flexible-packaging industry for food preservation. These in turn provide strong production bases for military needs.

The initial formal requirement for technology transfer from federal laboratories was the Stevenson–Wydler Act of 1980 (15 U.S.C. 3701 et seq.). Its intent was to maximize the benefit of taxpayer investment in federal R&D. The Federal Technology Transfer Act of 1986 (P.L. 99–502) provided specific requirements, incentives, and authorizations for federal laboratories to engage in technology transfer. It gave the director of each federal laboratory the authority to enter into cooperative R&D agreements (CRDAs) and to negotiate patent license agreements (PLAs) for inventions made at their laboratories.

The National Technology Transfer and Advancement Act of 1995 (P.L. 104–113) amends these laws to provide additional incentives, encouraging technology commercialization for both industry partners and federal laboratory inventors. This law seeks to promote industry's prompt deployment of inventions created under CRDAs by guaranteeing the industry partner sufficient intellectual property rights to the invention and by providing increased incentives and rewards to laboratory personnel who create new inventions.

A CRDA is probably the most powerful tool used for technology transfer. The CRDA is an agreement to cooperate and share intellectual property resulting from joint R&D efforts. It makes the technology, facilities, and people of Army laboratories available to commercial partners at an early stage of development, directly benefits the Army's mission from the partner's effort, and encourages direct interpersonal communication between scientists and engineers of the two sectors. Since a CRDA is not a procurement device (the government does not provide funding for services or products), military procurement procedures are not required.

PLAs are also important for commercializing inventions developed in Army laboratories. Each laboratory maintains a collection of patents developed by its scientists and engineers and markets those with potential commercial application. When licensed and commercialized, these inventions benefit consumers with new or improved products. Royalties are shared by the inventors (who receive the first $2,000 and thereafter 20 percent of royalties received) and the laboratory (which keeps most of the remainder). The ADTT program is initiating more aggressive patent marketing strategies to increase the level of Army patent licensing.

The construction productivity advancement research (CPAR) program was a cost-shared, collaborative R&D partnership between the U.S. construction industry and the Corps of Engineers designed to enhance construction industry productivity and innovation and benefit both industry and government. The Corps was authorized to use the capabilities and facilities of its R&D laboratories to pursue joint R&D, demon-

stration, and commercialization/technology transfer projects with industry partners. The projects were based on ideas from the construction industry, and the Corps could provide up to one-half the cost of a project. Through FY95, 72 projects were selected, with the industry providing $42 million and the Corps $27 million. CPAR products increased productivity and reduced costs. CPAR funding for FY96 and FY97 was deleted by Congress, and the program is currently inactive, except for completion of ongoing projects.

The Army has been a leader in technology transfer efforts from federal laboratories to the public and private domestic sectors for many years. Each Army laboratory and research, development, and engineering center (RDEC) has an Office of Research and Technology Applications (ORTA) to seek technology transfer opportunities and to serve as a point of contact for potential users of its technology. ORTAs assess laboratory technology that might have commercial applications, assist state/local governments, and develop CRDAs and PLAs in conjunction with private sector and laboratory technical and legal staffs. The ADTT program is intended to work through the decentralized but coordinated activities of the ORTA at each of the Army's laboratories and centers.

During FY97, 188 CRDAs and 14 PLAs were approved, for a total of 202 new agreements. Since most of the agreements negotiated from the inception of the program are still active, we track the cumulative totals, which were: 1,083 CRDAs, including CPAR CRDAs, and 87 PLAs for a total of 1,170 agreements (Figure VII–2). Total patent royalty income since inception of the program was $1.18 million, of which $0.255 million was received in FY97.

Recent cooperative effort examples include:

- The Army Research Laboratory (ARL) has teamed with a commercial partner to test and evaluate technology for locating and mapping nonmetallic buried pipe

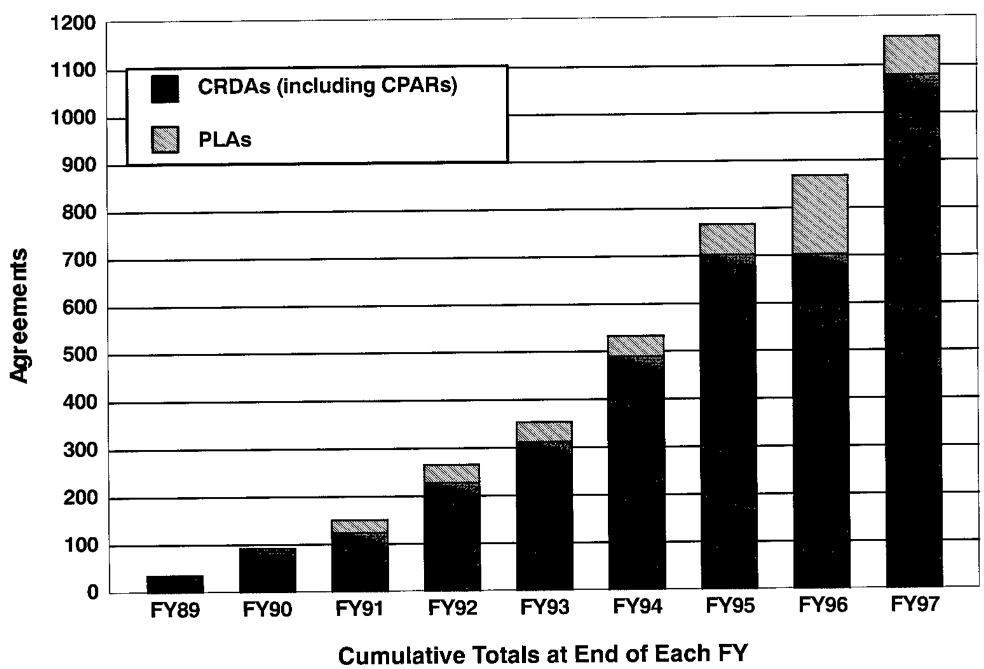


Figure VII–2. Army Accepted Cooperative Research and Development Agreements and Patent License Agreements

and shallow tunnels. The ability to locate nonmetallic pipe (e.g., polyvinyl chloride (PVC)) would be extremely useful to the utility industry). Military applications of this dual-use technology could include detection of buried plastic mines and the ability to locate and map enemy tunnels.

- The Corps of Engineers Waterways Experiment Station (WES) has awarded multiple patent licenses for its patented CORE–LOC technology. CORE–LOC is a new concrete armor unit used to protect navigation and coastal shore structures (e.g., breakwaters). Unlike most other types of concrete armor units, CORE–LOC is placed in a single layer. With its low packing density, CORE–LOC significantly reduces on-slope concrete volume and can save project owners over 50 percent of the cost associated with other concrete armor units.

- The life support for trauma and transport (LSTAT) is a transportable, stretcher-based mini-intensive care unit that was jointly developed through a cooperative agreement involving industry and investigators at the Walter Reed Army Institute of Research. The LSTAT incorporates state-of-the-art resuscitative and life-sustaining capabilities in a universally adaptive platform for trauma management, unattended patient support, and transport of medically unstable patients. The system has broad dual-use applications in military and civil settings.

- The Tank–Automotive RDEC (TARDEC) has two CRDAs with the private sector for R&D on blind spot monitoring systems for vehicles to help avoid collisions. The blind spots around vehicles are serious hazards when drivers change lanes or merge with moving traffic. Results of these efforts could be applied to private and commercial vehicles, large and small, to help avoid many injuries each year.

In the future, the Army will continue to support ADTT through support of active ORTAs. Army CRDAs should be established to develop technology that contributes to the national competitive position or the public good in health, education, or environmental areas. Additionally, CRDAs should be sought in technology areas important to the laboratory or center.

The Army is also seeking to coordinate and increase its marketing efforts for technology transfer and patent licensing. Individual laboratories and centers are encouraged to aggressively market the expertise and unique capabilities and facilities of their organizations as well as their technologies. Attendance at technology transfer shows and conferences is also an important outreach effort. The Army is expanding its marketing efforts in conjunction with the Federal Laboratory Consortium, a formal government-wide network of all ORTAs, which supports extensive outreach and referral efforts. Additionally, we are targeting relationships with high-technology small businesses.

4. Technology Transfer in Medical Research and Development

The primary purposes of military medical R&D are preventing injury and illness in the field and sustaining life and health. However, there is probably no other DoD program whose research results are so directly applicable to the worldwide civilian community. Advances in antimalarial drugs, vaccines for many diseases, blood and tissue substitutes, and the treatment of trauma are all of direct benefit to people. The benefits are not limited to the United States; for example, DoD research teams deployed in Egypt, Taiwan, Indonesia, Thailand, Malaysia, Brazil, and Peru have worked directly on civilian health problems that not only are threats to possible future deployment of American troops, but also are presently infecting local populations. Medical R&D also contributes to establishing national and international standards for nutritional requirements of special populations and exposure to occupational health hazards, as well

as developing and demonstrating modeling technologies for predicting the effects of exposure to health hazards. For example, the Department of Transportation has used the Army's blast overpressure injury model to predict injuries from driver and passenger air bags.

The Army's first collaborative efforts in medical R&D were basic screening and testing agreements, under which a company or university would submit compounds for testing for a specific property, such as antimalarial activity. These early agreements quickly evolved into more extensive collaborative efforts where each partner would expend resources toward the development of a product and share the results of its efforts to meet the Food and Drug Administration's regulatory process. The development of mefloquine is a classic example of an early cooperative effort between the Army and industry that predates the Federal Technology Transfer Act. Each party funded its own preclinical and clinical studies with its own unique resources and shared and consolidated the data. The Army medical R&D program over the past decades has fostered thousands of cooperative relationships with academia and industry.

The Army has numerous compounds, some with commercial value and some with military value. For example, the Army is developing several compounds that appear to be active against malaria, leishmania (a problem for some Operation Desert Storm veterans), and pneumocistis , which kills many AIDS patients. A collaborative effort on such compounds allows industry and the Army to leverage each other's resources. The Army also has several products or technologies useful to the research and commercial communities, from vaccine production tools to qualitative and quantitative assays.

The Medical Research and Materiel Command (MRMC) is initiating an intellectual property and transactional management project to identify established and emerging intellectual property practices in industry and adopt those practices where possible. Initial practices will include routine review of the *Official Gazette* and targeting marketing strategies for identified technologies.

The MRMC encourages research in relevant fields at colleges and universities, and cooperates with research efforts of the National Institutes of Health, the National Science Foundation (NSF), and other government agencies. These research programs complement and exploit civilian science and technology efforts over the full research and development spectrum. The commercial sector is encouraged to address problems of military interest through the SBIR program. The Federal Technology Transfer Act is the authority for numerous MRMC CRDAs, primarily with pharmaceutical, chemical, and biotechnology firms. Medical R&D is an international program of broad and effective current and potential opportunities in developing and developed nations. The MRMC participates in information and data exchange programs, cooperative developments, NATO comparative tests, foreign weapon evaluations, and symposia and meetings.

5. Dual-Use Information

As defined by public law, dual-use technology has both military and civilian applications. Most dual-use technology is generated through spin-off (commercialization of military technology for civilian applications; e.g., IR sensors) or spin-on (military adaptation/application of commercial technology; e.g., state-of-the-art computer hardware/software).

The Army is an aggressive partner in dual-use R&D, with the primary motivation of leveraging commercial technology for military applications. The Army uses more CRDAs than the other two services combined to leverage the R&D investment by industry. The Army also uses the Advanced Concepts and Technology II (ACT II) program to support Training and Doctrine Command (TRADOC) battle laboratories and their Army laboratory/R&D center partners in evaluating commercial concepts and technology with high potential military utility (Section D).

The Army targets dual-use projects in combat vehicles and automotive technologies, aviation, medical research and technology, construction engineering, environmental research, pollution abatement/control, telecommunications, sensors, and individual soldier technology. Examples include:

- ARL's federated laboratories heavily leverage industrial and academic basic research infrastructure and expertise through cooperative research agreements in areas where commercial industry has the technical lead and incentive to invest (Chapter V).
- The National Automotive Center (NAC) serves as a focal point for dual-use technologies and application to military ground vehicles. An umbrella CRDA with General Motors, Ford, and Chrysler provides the basis for significant technology transfer (Section D).
- The National Rotorcraft Technology Center (NRTC) established a government/industry partnership that combines the resources of the government, the rotorcraft industry, and academia, and identifies and develops dual-use rotorcraft technologies (Section D).

The Army is also a participant in the DoD Dual-Use Applications Program (DUAP) S&T initiative. This initiative provides incentive funding to the services to support dual-use technology development projects. These funds are matched by service funds, and the total of these two is matched by the industry partner(s). DUAP projects therefore involve a mix of Army (25 percent), DUAP (25 percent), and industry (50 percent) funding, using cooperative agreements or other transactions for their execution. The cost-sharing by industry is a concrete demonstration of its commitment to exploit the resulting technology for commercial as well as military applications.

In FY 97, the Army gained DUAP support for 38 projects under the S&T initiative, resulting in over $21 million in DUAP funding for Army S&T projects. Additional DUAP funding will be available in FY98 for matching by Army and industry, increasing the overall Army investment in dual-use technology and leveraging on the industry's share in the development of these technologies.

C. TECHNOLOGY COOPERATION WITH NONPROFIT INSTITUTIONS

Universities provide advanced scientific and engineering education, critical to both military security and economic strength. Universities have traditionally performed a major part of the nation's long-term basic research. Since the 1940s, the Army has supported academic work in areas of potential military interest. In response to evolving social, economic, and budget realities, Army support to universities has emphasized Army problems and efforts to apply research results to commercial or dual-use products. It also has emphasized support to people and institutions traditionally underrepresented in national scientific and engineering efforts. The Army is increasing its efforts to support interest in science and engineering careers in colleges and universities, high schools, and elementary schools.

The Army cooperates with nonprofit institutions (including universities) by means of CRDAs and PLAs, and the Army STTR program uses small businesses to commercialize technology developed in these institutions.

The Army is the government sponsor for two FFRDCs and, as appropriate, uses the unique capabilities of FFRDCs sponsored by others.

1. Programs With Academia

The Army's 6.1 program, approximately half of which supports basic research at universities, is a key leveraging mechanism. These research investments will produce results that impact the Army's future capabilities through the emerging technology areas and through breakthroughs. This program is described in more detail in Chapter V. The Army also maintains a European

Research Office and supports a small amount of research at universities in Europe and Japan, in order to gain access to unique foreign capabilities (Section E).

a. University Research Initiative and Centers of Excellence

In addition to providing support to individual researchers, the Army sponsors research through two university-centered programs: the Army centers of excellence (COEs) and the series of DoD projects known as the university research initiative (URI). Both address specific Army needs (Figure VII–3). The URI's science and engineering education programs also address this country's need to increase its pool of advanced scientists and engineers by supporting nearly 400 science and engineering graduate students annually.

University COEs provide Army support to graduate-level research and education. The Army's investment in these centers is highly leveraged, for the centers have attracted additional sources of support. Through the COEs and URI centers, the Army participates with more than 30 American universities. Both COE and URI are described in more detail in Chapter V.

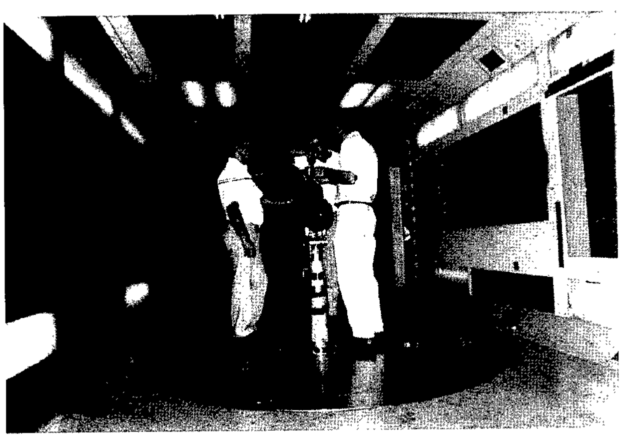


Figure VII–3. Funding for University Research Efforts Includes the Army Centers of Excellence and the University Research Initiative Centers

b. Interactions With the National Science Foundation

Through a memorandum of understanding, the Army and NSF formed a consortium that includes eight universities to attack critical problems in high-speed microelectronics, millimeter waves (MMWs), and communications research. NSF provides grants, and the Army provides access to what is considered DoD's best microelectronics fabrication facility. While there, students and their mentors conduct research that benefits academia and the government. Also, ARL is an industrial board member of the Software Engineering Research Center sponsored by NSF.

2. Historically Black Colleges and Universities and Minority Institutions

Recognizing that historically black colleges and universities (HBCUs) and minority institutions (MIs) are national resources with high enrollments of underrepresented minorities, DoD has encouraged its agencies to develop programs that enable these institutions to increase the number of minority graduates in the physical sciences, mathematics, and engineering.

It is Army policy that:

- At least 5 percent of research, development, and acquisition (RDA) funds going to higher education institutions are to be awarded to HBCUs or MIs.
- Each RDEC/laboratory is to foster a linkage agreement with an appropriate HBCU or MI.
- The Army Research Office (ARO) facilitates research collaborations between HBCU and MI COEs.
- All new Army COEs are to have an HBCU or MI member.
- Information sciences and training research COEs are headed by HBCUs.
- Each Army COE is to have a proponent laboratory/RDEC, which provides the

COE Executive Advisory Board Chairman.

The Army Materiel Command (AMC) has made progress in achieving these goals:

- Federated Laboratory Consortia established by ARL have HBCU or MI members.
- Cooperative research programs have been established between major universities and HBCUs and MIs. For example, the Army High Performance Computing Research Center, established by ARO and managed by ARL, brings together the University of Minnesota and four HBCU partners, Howard University, Jackson State University, Alabama A&M University, and Clark Atlanta University. The multimillion dollar program provides funds for research, equipment, and infrastructure support.
- The HBCU and MI COE program was established by ARO in 1992. The first two centers were located at Clark Atlanta University and Morris Brown College. Both centers had 5-year programs totalling approximately $3.75 million each. The Clark Atlanta program specialized in information sciences research, while the Morris Brown program focused on training research to determine how future soldiers can maintain peak proficiency during combat operations.

The ARO periodically publishes brochures highlighting accomplishments of the AMC HBCU and MI program. Chapter V contains additional information about ARO's COEs.

AMC's research programs and other opportunities for HBCUs and MIs are the most innovative of the entire defense department. Through the "one-source" approach, the command has collected and focused its efforts into a model program.

3. Federally Funded Research and Development Centers

FFRDCs, which perform, analyze, integrate, support, or manage basic or applied R&D, receive at least 70 percent of their financial support from the federal government. FFRDCs have greater access to government and supplier data, employees, and facilities than is common in a normal contractual relationship. (A master list of these activities is maintained by the NSF.) The Army is the government sponsor for two FFRDCs: the Arroyo Center, a research division of RAND, Santa Monica, California; and the Mitre Corporation's command, control, communications, and intelligence (C^3I) operating division in Washington, DC.

Staff at the Arroyo Center perform studies and analyses for the Army. This FFRDC mission is to provide objective and independent analytical research on major Army policy, management, and technology concerns, with an emphasis on mid- to long-term problems. Efforts include policy and strategy analyses, research within the framework of the Army's future force needs and employment concepts, analyses and testing of alternative policies for manning, training, and structuring the Army of the future, analysis of issues associated with future readiness and sustainability, and studies in applied technology.

These analyses identify and assess the ways in which technological advances can enhance the future Army's capabilities. Examples include an assessment of advanced light armored vehicles, terrorists and biological weapons in the 1990s, and the Army's role in space.

The Mitre C^3I FFRDC has two divisions, the Mitre Bedford Division sponsored by the Air Force and the Mitre Washington Division sponsored by the Army (the "primary sponsor" is in the Office of the Secretary of Defense). The mission of this FFRDC is to conduct studies and analyses, provide systems engineering support, and conduct laboratory experimentation based on sponsors' requirements. Mitre conducts its own in-house R&D, tailoring the programs to spon-

sors' missions. An important link between the Air Force and the Army, Mitre provides an objective, technical basis for the conception, analysis, selection, design, and evaluation of information and communications systems.

4. Outreach Programs

Studies by NSF and the National Academy of Sciences have indicated that in order to meet the scientific and economic challenges expected in the year 2000, the nation will need to attract and retain more students in degree completion in science, mathematics, and engineering. Approximately 70 percent of the adults entering the work force between now and the 21st century will be women and minorities. Yet, women and minorities are two groups historically underrepresented and underutilized in science and engineering. To counteract this trend, DoD task force studies have urged the creation of intervention programs designed to increase the availability of scientific, engineering, and technical skills in the DoD work force. The Army's outreach efforts are described below.

a. Women in Science and Engineering

Women are significantly underrepresented in engineering and the physical sciences, compared with their participation in the general work force. Despite significant increases during the last generation, only about 9 percent of all working engineers are women, and in recent years the proportion of new women engineering graduates has remained constant at about 16 percent. Absent significant intervention or major social change, the proportion of women in engineering is therefore likely to increase only gradually and then level off. Perhaps because of their scarcity or because only the best survive, women engineering graduates receive 103 percent of the starting salary of men.

The Army has outreach activities whereby it employs women students from local universities, studying engineering and the sciences, in a cooperative education program that alternates school and work cycles. High school and college summer employment opportunities are also available (Figure VII–4). In addition there are employment programs for women instructors in high school and higher education who are interested in keeping current in their areas of technical expertise.

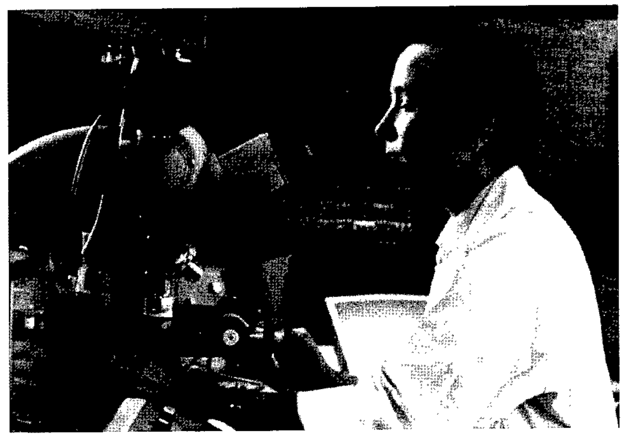


Figure VII–4. Army Outreach Programs Include Attracting Women Scientists and Engineers

b. Youth Science Activities

Increasing the scientific and technical human resources available to both the government and private sectors is necessary to maintain future U.S. competitive advantage. To accomplish this, education, especially in science, mathematics, and technology, is critical.

Many Army laboratories have outreach programs that actively support innovative ways to improve S&T education. There are adopt-a-school, education partnerships, and student/faculty employment programs.

Services provided by hundreds of Army scientists and engineers have helped to improve science, mathematics, and technology education through technical lectures, career education, science fair judging, field trips, mentoring student research projects, library and computer support, loaning/donating surplus equipment, and teaching classes or assisting in the development of courses and materials.

The Army also sponsors specific youth programs at the high school level to promote partici-

pation in science and engineering activities. For example:

- The Junior Science and Humanities Symposium (JSHS) was initiated by the Army in 1958 and joined by the Office of Naval Research and U.S. Air Force after 1995. Its activities promote research and experimentation at the high school level, identify and recognize talented youth and teachers, and increase the country's pool of young adults interested in pursuing careers in the sciences. JSHS reaches over 10,000 students and 250 teachers annually.
- The Uninitiates Introduction to Engineering (UNITE) program provides socially and economically disadvantaged secondary school students with tutorial assistance, primarily in mathematics. Through their participation, these students can acquire the prerequisites for beginning science and engineering careers in college. The program began in 1980 and more than 3,500 students participated during its first 17 years. Of these, 40 percent have graduated from college through 1997, with 50 percent in technical fields, 45 percent in engineering, and 5 percent in the humanities.
- The Research and Engineering Apprenticeship Program (REAP) is a cooperative work-study program that gives high school students hands-on experience in R&D activities through interactions with mentors. Drawn from socially and economically disadvantaged groups, as defined in P.L. 95–507, these students are selected on the basis of their potential to pursue careers in science and engineering. The program began in 1980. At least 1,700 students have participated through 1996. Of these, 90 percent entered college, with 86 percent of these undertaking engineering or science studies.
- The International Mathematical Olympiad (IMO) was started by eastern European countries following World War II as a means to encourage young mathematicians. The United States began participating in 1976 with the selection of an American team under the auspices of the Mathematical Association of America. Along with the Navy, the Army contributes to this effort by providing funds. Annually six American students (from over 400,000 that compete) and three coaches travel to the site of the Olympiad for approximately 10 days of individual competition. American students often achieve first place honors at the IMO, which is one of the most prestigious competitions in mathematics at this level. In 1994, each U.S. team member scored a perfect score for the first time in the history of the program.
- Since 1960, the Army has sponsored special awards in the nationwide science and engineering fairs to stimulate and encourage the future technical development of our nation's youth. Army personnel participate as judges in regional, state, and international fair competitions and present awards on behalf of the Secretary of the Army. The International Science and Engineering Fair (ISEF) brings together two students from each of approximately 400 regional and state science fair competitions that involve over 100,000 high school students. Each winner in 14 scientific and engineering categories is awarded a certificate of achievement, a $3,000 prize, and a gold medallion. In addition, one student is selected to attend the London International Youth Science Forum at the University of London, where students from over 35 nations participate in a 2-week program of scientific lectures and cultural tours. Two students are selected to visit Tokyo as part of an exchange program between the United States and Japan, where the two Army winners are recognized at the Japan Student Science

Awards Ceremony. The three trip winners each receive a certificate of achievement, a medallion, a $3,000 prize and $150 from the Association of the United States Army.

D. TECHNOLOGY LEVERAGING PROGRAMS

Army S&T makes up less than 1 percent of the total national investment in R&D so the Army leverages external R&D activity to meet its warfighting needs. This R&D comes from other federal government organizations, universities and nonprofit organizations, U.S. industry, and foreign sources.

The Army technology transfer program systematically leverages each of these sources of technology.

The Army's goal is to form cooperative programs with these sources, sometimes involving cost-sharing. In other cases, the Army seeks to influence the direction of development, or maintain a "smart buyer" capability within the Army.

This section describes the Army's approach to technology leveraging with the major external sources of technology available within the United States. Section E describes the Army's approach toward leveraging foreign sources of technology.

1. Independent Research and Development Program

Independent research and development (IR&D) activities are planned, performed, and funded by companies in order to maintain or improve their technical competence or to develop new or improved products. Industry IR&D efforts amount to more than $2 billion annually. A significant portion of a company's annual IR&D expenditures and its companion bid and proposal (B&P) costs can be recovered later in the overhead portion of its contracts with commercial concerns and with DoD. The FY92 Defense Authorization Bill simplified the procedure used to reimburse companies for relevant IR&D work. Beginning in FY96, contractors have been reimbursed for up to 100 percent of their IR&D expenditures that meet "potential interest to DoD" criteria.

Prior to FY93, company IR&D programs were assigned to a lead service for technical review and cost-recovery negotiations. The current law eliminates these assignments and focuses on utilization of industry's significant IR&D technology resources through technical interchange meetings. IR&D technical interchange meetings are arranged by mutual agreement between the company and the government to discuss technology or product development projects. These meetings promote face-to-face technical interaction between contractors and the government, provide feedback to companies so that IR&D activities are aligned with future government needs, and permit government participants to visit the contractors' facilities and view operations. Many of the service and company assignments established prior to FY93 have been mutually beneficial and will be continued. Company and government personnel are free to continue frequent informal dialogue and technical information exchange even though they no longer maintain a formal relationship. There is no required frequency of meeting, but many contractors express a desire to meet at least annually.

The projected downward trend of DoD expenditures affects the future of industry IR&D activities. Rigorous cost competition in the defense industry has caused pressure to reduce overhead (including IR&D), and decreasing sales have reduced the base against which IR&D costs can be charged. The likely result—erosion of industry's IR&D technology base—led to the present cost-recovery process and a broadened set of cost-recovery criteria as means to limit this loss of U.S. technical strength and to encourage interest in defense conversion and in dual-use technology. The current criteria for reimbursement for IR&D include:

- Enabling superior performance of future weapon systems and components.

- Reducing acquisition costs and life-cycle costs of military systems.
- Strengthening the U.S. defense industrial and technology base.
- Enhancing U.S. industrial competitiveness.
- Promoting the development of critical technologies (as identified by DoD).
- Increasing the development of technologies useful in both the public and the private sectors.
- Developing efficient and effective technologies for achieving environmental benefits.

Improved communications between industry and government on IR&D is at the heart of successful leveraging of IR&D, and continues to be emphasized through frequent interaction of Army leadership and industry IR&D representatives. Recent improvements to the IR&D reporting and review processes will significantly enhance the Army's ability to strategically leverage IR&D developments. These improvements include compact disk–read only memory (CD–ROM) technology applied to the IR&D database at the Defense Technical Information Center (DTIC), a new DoD instruction on IR&D that will ensure more complete reporting of IR&D to government, and more complete review of appropriate IR&D by the Army. An IR&D Website on the Internet is maintained by the Air Force IR&D manager:

http://www.afmc.af.mil/STBBS

This service will provide contractors access to DoD planning information to focus their IR&D expenditures on relevant DoD technology needs. The Air Force Internet site will also contain a schedule of IR&D information exchange meetings to encourage government personnel participation in these information exchanges.

Further improvement to the IR&D process has been attained through the establishment of a joint senior-level Technical Coordination Group (TCG) to oversee and manage DoD's IR&D program. This TCG for IR&D is chaired by the Deputy Director, Defense Research and Engineering (Office of Laboratory Management/Technology Transition) with membership by senior civilians from each of the services. The primary purpose of the TCG is to manage DoD communications with industry concerning defense technology planning and requirements.

The Army receives the IR&D database from DTIC. The IR&D database on CD–ROM, issued by DTIC beginning in FY94, has significantly enhanced the Army's ability to leverage IR&D. The CD–ROM contains the entire database of current industry IR&D technology developments, and permits every Army activity to maintain the complete IR&D database of industry's IR&D expenditure on a personal computer. Once full industry IR&D reporting to DTIC is achieved, as emphasized in the recently revised DoD Instruction on IR&D, the CD–ROM will become a reliable and comprehensive source of industry technology.

Through use of the IR&D database on CD–ROM, local Army IR&D managers should be able to better target IR&D projects of interest, vector project write-ups to local scientists and engineers, and follow up positive in-house responses by establishing technical information exchange meetings. These meetings could be a vehicle whereby the Army communicates technology needs to industry, and industry communicates IR&D progress and plans to Army scientists and engineers.

2. Advanced Concepts and Technology Program

TRADOC's battle laboratories have been chartered to experiment with changing methods of warfare, beginning with the battlefield dynamics and with soldiers and leaders as the center of focus. While the battle laboratories were started as a means to focus internal TRADOC activities, AMC has established a partnership with the battle laboratories in support of this experimentation. The Advanced Concepts and

Technology (ACT II) program provides a unique environment for combining the warfighting expertise of the battle laboratories with the technical expertise of AMC's RDECs and the Army laboratories. This partnership forms the basis for ACT II projects that facilitate experimentation in seeking solutions across the spectrum of doctrine, training, leader development, organization, materiel, and soldier (DTLOMS) systems.

Since its inception in 1994, ACT II has been directed to provide direct support to the TRADOC battle laboratories and to the Army Chief of Staff for the Louisiana Maneuvers Task Force. With the user more actively involved, ACT II allows better evaluation of new capabilities enabled by ACT II technologies, and provides accelerated support from the S&T community. Today, ACT II is sponsored by the Army Chief of Staff and ASA(RDA) and managed by the ARO–W. TRADOC, AMC, and ARO–W collaborate to build ACT II partnerships between the Army, industry, and the academic community.

ACT II supports battle laboratory experiments through competitive funding of industry's most advanced technologies, prototypes, and nondevelopmental items. The program provides funding to demonstrate the technical feasibility of such technologies that, if successful, may:

- Shape TRADOC requirements.
- Be integrated into existing Army R&D programs.
- Be selected for the Army Warfighting Rapid Acquisition Program (WRAP).
- Transition directly to an existing end item.

ACT II does not fund established technology base programs, but seeks unconventional approaches to address Army needs. Direct access to the commercial market is intended to improve the definition of user requirements, shorten the acquisition cycle, and reduce development costs. By comparison, under the conventional acquisition process, long lead times are often required for research ideas to reach the soldier. Because of its small size (ACT II funds a maximum of $1.5 million per project) the program generally supports highly leveraged efforts that appear likely to have important impacts on the Army if successful. ACT II projects are frequently cost-shared or leveraged efforts, partly supported by others.

ACT II projects are centrally solicited using a Broad Agency Announcement (BAA) prepared by ARO–W. The BAA requests that prospective offerors initially submit a two-page concept paper highlighting the technical and warfighting merits of their concept. Those submitting concept papers found to be technically feasible and most desirable in terms of warfighting merit are invited to prepare full proposals (limited to 25 pages plus a separate cost estimate). Highly rated proposals are similarly evaluated and ranked according to warfighting merit, and centrally approved for negotiation and award by the ACT II Technical Evaluation Board. The resulting contracts are awarded through various Army procurement offices and are jointly managed by battle laboratory project officers and technical experts in appropriate Army laboratories and RDECs.

Since 1994, its inaugural year, ACT II has funded and completed a total of 107 projects (28 projects in 1994, 35 projects in 1995, 25 projects in 1996, and 19 in 1997). To date, 27 projects from 1994 and 1995 have been identified as meeting the program objectives for technology transition and integration. These projects are (1) being developed further through Concept Exploration Program funding, (2) integrated into existing acquisition programs as product improvements, or (3) included among projects funded through WRAP. ACT II funding was $10 million in FY94, $40 million in FY95, $13 million in FY96, $12 million in FY97, and approximately $11 million in FY98.

ACT II is an ongoing program within the Army. An industry-focused preproposal conference for the FY98 ACT II cycle was held in April 1997. The BAA for the FY99 cycle will be released

in May 1998, with concept papers due in June 1998. Full proposals will be invited in July 1998 and responses evaluated during August–September. Contracts for the FY99 program should be signed during December 1998.

ARO–W maintains a Website for ACT II. In addition to providing current ACT II information and descriptive project summaries from previous years, offerors can download the current solicitation and necessary forms for preparation of concept papers or full proposals. The Website address is:

http://www.aro.ncren.net/arowash/rt/actii.htm

3. Army Efforts With Other DoD Agencies

Many Army S&T activities are coupled with programs of the other services and with other DoD agencies. The major agencies with which the Army interacts are the Defense Advanced Research Projects Agency (DARPA), the Defense Special Weapons Agency (DSWA), the Ballistic Missile Defense Organization (BMDO), and the U.S. Special Operations Command (SOCOM). Working relationships between Army and agency technical staffs have included coordinated program planning, parallel funding, and, in some cases, joint agency–Army program management by Army S&T organizations.

a. Defense S&T Reliance

In November 1991, all three service acquisition executives directed full implementation of Project Reliance in their respective services. In November 1995, the Defense S&T Reliance Executive Committee was formed to strengthen Reliance's role in the DoD strategic planning process and to continue to improve service/agency S&T coordination. Implementation of Defense S&T Reliance also responds to and provides input to a number of management functions and planning processes, including the budget planning process and the development of technology investment plans through the *Defense Technology Area Plan*, the *Joint Warfighting Science and Technology Plan*, the *Basic Research Plan*, and updates of the *Defense Science and Technology Strategy*.

The goals and objectives of Defense S&T Reliance reflect the enduring challenges that face the defense S&T community. They are to:

- Enhance the quality of defense S&T.
- Ensure the existence of a critical mass of resources that will develop world-class products.
- Reduce redundant S&T capabilities and eliminate unwarranted duplication.
- Gain productivity and efficiency through collocation and consolidation of in-house S&T work, where appropriate.
- Preserve the service's vital mission-essential capabilities

Reliance agreements involve joint planning, collocated in-house work, related contract work, and lead service/agency assignment. The leveraging is based on the fact that no service's individual S&T accounts can fund all the R&D activities that that one service needs.

b. Defense Special Weapons Agency and Treaty Verification

The Chemical Weapons Convention Treaty includes a provision for compliance monitoring via on-site inspection. DSWA is the DoD executive agent for research, development, test, and engineering (RDT&E) programs related to treaty verification and compliance, while the Army is the DoD executive agent for chemical and biological defense. Accordingly, the Army and DSWA have created a working environment via a memorandum of agreement (MOA), in which the Army is the lead performer for sampling methodology and audit trails, chemical agent sensor assessments, sampling and protective devices and equipment, and field demonstrations of available technology. The U.S. Army Edgewood RDEC is coordinating Army technology efforts in this area. The program is funded by DSWA.

The MOA was signed in FY90, and detailed technical planning and implementation continues.

c. Defense Advanced Research Projects Agency

DARPA was founded in 1958 to foster innovative military R&D. It has a long history of close cooperation with the Army in pursuit of advanced technology for future battlefields. DARPA works closely with the Army and other service users to ensure that it prioritizes emerging technologies that will be most important in meeting the nation's security needs. DARPA provides the services with access to the nation's research capabilities in industry, academia, and government research centers and laboratories for the solution of emerging military requirements. Army efforts in conjunction with DARPA to meet warfighting needs include:

- Hybrid electric power.
- Advanced seeker technology.
- IR focal plane arrays.
- Missile defense.
- Counter sniper.
- Advanced sensors such as synthetic aperture radar.
- Small arms protection for the individual soldier.
- Communications.
- Helmet-mounted displays.

d. Ballistic Missile Defense Organization

The Strategic Defense Initiative Organization, chartered in 1984 to manage DoD's efforts in ballistic missile defense, is now the Ballistic Missile Defense Organization (BMDO), which reports to the Under Secretary of Defense for Acquisition and Technology. While BMDO is the focal point for policy and program formulation, the operational aspects of ballistic missile defense (BMD) work are performed through the BMD executive agents and their research facilities, service commands, and other installations at various locations throughout the United States.

Volume II, Annex D, contains a detailed description of the Space and Missile Defense Command (SMDC) roles, responsibilities, and contributions with respect to BMD, SMDC, and the Army S&T program.

e. U.S. Special Operations Command

SOCOM, established in 1987, unifies all continental-based special operations forces under a single commander. Its unique responsibilities include the following missions: unconventional warfare, direct actions, special reconnaissance, foreign internal defense, counterterrorism, psychological operations, civil affairs, counterproliferation, and information warfare. For these missions, SOCOM was granted the authority to develop and acquire special operations-peculiar equipment, materiel, supplies, and services. In 1992, Congress recognized that SOCOM R&D funding was inadequate to support the command's technology needs and directed that SOCOM compete for other agencies' technology base development needs. SOCOM's S&T budget is principally for technology demonstration (80 percent), with lower funding in technology development (20 percent).

An assessment by SOCOM, to include the U.S. Army Special Operations Command, indicates that many of the Special Operation Forces (SOF) technology needs are being or can be addressed in Army laboratories and centers, and that the SOF community can maximize its return on investment by coupling with current and planned Army technology efforts. One example is the 21st Century Land Warrior program. SOCOM has also participated in intercommand seminars, exercises, and equipment expositions as well as in AMC's Technology-Based Seminar War Games. The SOF play a role in TRADOC's development of the soldier, participate in the Army's Future Soldier System Tech Base Executive Steering Committee, and formally review the Army's work packages and identify the projects of most value for resolving materiel needs.

Volume II Annex F discusses SOCOM's current technology objectives, strategy, and programs for improving its operational capabilities, and the integral part that technology plays in the command's recently published version of its future vision into the 21st Century, entitled SOF VISION 2020.

f. Scientific Services Program

ARO monitors this competitively awarded program: short-term analysis service (STAS); laboratory research cooperative program; conferences, workshops, and symposia; the Summer Faculty Research and Engineering Program (SFREP); the Summer Associateship Program for High School Science and Mathematics Faculty, and the Postlaboratory Research Cooperative Program/Postsummer Faculty Research and Engineering Program.

The STAS program, the largest, processes between 200 and 300 projects annually, originating from all three services and other government agencies. The STAS objective is to competitively award short-term projects to academic or small business scientists who complement government expertise. Awards are usually less than $100,000 each (although special requests up to $250,000 are considered), are less than a year's duration, and the award is usually made within 30 days of receipt of the work order. Under the SFREP, about 150 faculty are placed at Army laboratories or centers each year. The total scientific service program annually awards about $10–$15 million.

4. Army Efforts With Other Federal Agencies

Because of its scarce resources, the Army needs to work with other government agencies to fully leverage its R&D efforts. The Army cooperates with many other federal agencies to accomplish missions of mutual interest, obtain access to unique capabilities, and provide other agencies access to unique Army capabilities. A major effort with NASA allows the Army to leverage NASA's capabilities that are closely related to Army needs.

a. Activities With NASA

In 1965, AMC and NASA signed an agreement for joint participation in aeronautical technology related to Army aviation. This agreement, issued to what is now the Aviation and Missile Command (AMCOM), permitted the Army to use NASA's 7- by 10-foot subsonic wind tunnel at NASA's Ames Research Center. The agreement now includes the ARL Vehicle Technology Center at NASA Langley and Lewis Research Centers (LaRC and LeRC, respectively) and two Joint Research Program Offices at LaRC. The agreement also includes elements of ARL, AMCOM, and the Communications–Electronics Command (CECOM) as illustrated in Figure VII–5. This cooperative arrangement allows Army engineers direct access to NASA's world-class research facilities. For example, while the Army has access to facilities at the Ames Research Center alone worth more than $1 billion (with an annual operating cost of more than $60 million), the Army directly incurs less than one percent of the annual cost.

Army scientific and engineering personnel may be assigned within the NASA organization but they work on programs of Army interest as negotiated by the Army director with their NASA division or branch chiefs. This ensures that Army resources are focused on Army priorities and permits both the Army and NASA to accomplish more with less.

Thirty years of Army–NASA cooperation has let the Army leverage NASA resources and programs and contributed to advancement of an integrated civil and military technology base.

b. Cooperation with Drug and Law Enforcement Agencies

In December 1990, the ASA(RDA) Deputy for Combat Service Support was designated to represent ASA(RDA) with all non-DoD agencies and all DoD offices, agencies, and departments

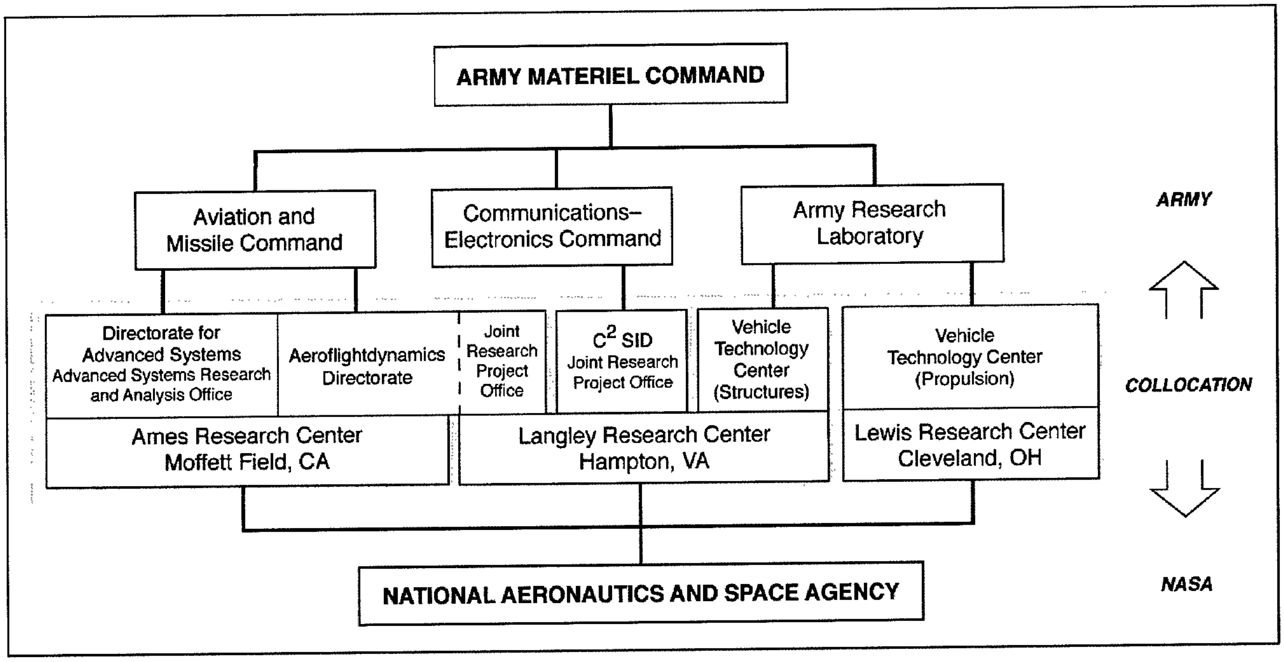


Figure VII–5. Army–NASA Joint Aeronautical Research Locations

involved in counterdrug (CD) activities. This established the Army's Counterdrug RDA Office.

The Army currently provides management oversight on 17 CD programs in a variety of technological areas, from nonintrusive inspection to automated systems.

Diminishing resources and an escalating threat from drug traffickers resulted in the development of the Army's Counterdrug Technology Information Network (CTIN), which is based on the premise that information about available technologies can help bridge the gap between threat and resources. CTIN also capitalizes on technology as a force multiplier and allows the CD community to achieve economies of scale via cooperative acquisitions. CTIN contains descriptions and points of contact for several hundred systems and techniques that may help counter the illegal narcotics threat.

The first part of CTIN is a Website that may be viewed by anyone and permits sharing information of interest to the CD community. It provides links to other CD sites and offers a mailing list.

The second, main, part of CTIN is a bulletin-board-like system (BBS), hidden from the public. The BBS provides access to special information and provides a question-and-answer forum. The BBS can be accessed via modem or through the Internet, using either a Macintosh- or Windows-based personal computer. The U.S. Army Counterdrug RDA Office must approve access to the BBS.

The CTIN supports the DoD and the Department of Justice (DOJ) memorandum of understanding (MOU) and identifies existing DoD equipment, ongoing technology development programs that can be shared, and new military technology projects that solve problems common to the military and law enforcement communities. As part of that MOU, a Joint Program Steering Group was formed at DARPA. The DoD/DOJ relationship is based on common interest derived from emphasis on a traditional military mission called operations other than war (OOTW). In general, law enforcement applications require technology and systems that are affordable, safe to use on or around people with varying medical conditions, acceptable to the public, and consistent with the constitutional

rights of all involved. Specific areas of interest include:

- Concealed weapons detection.
- Less-than-lethal technology.
- Tracking, tagging, and status monitoring.
- Interactive simulation and training.
- Explosives detection, neutralization, and disposal.
- Small mobile sensor technology.
- Urban mapping and three-dimensional scene generation.
- Advanced sensor integration.
- Safe gun technology.
- Information technology.
- Biomedical.
- Portable power.
- Antisniper.
- Advanced body armor.

c. Cooperation With Other Agencies

A dozen years of joint research on robotics with the Department of Commerce's National Institute of Standards and Technology (NIST) have led to success in the application of flexible computer architectures to DoD unmanned ground vehicle testbeds for hazardous military missions such as reconnaissance. This experience has allowed the Army and NIST to collaborate on civil programs, such as the Department of Transportation's Intelligent Vehicle Highway System. There are efforts to find additional areas for potential cooperation with NIST.

As part of the Strategic Environmental Research and Development Program (SERDP), joint research is being conducted with the Environmental Protection Agency (EPA) and the Department of Energy (DOE) on a multitude of environmental topics. For example, a national environmental technology test site program, managed jointly by the Army, Navy, and Air Force, has been developed to demonstrate, evaluate, and transfer innovative cleanup technologies from R&D to full-scale use. Another example is the partnering between the Army, other services, DOE, and EPA for the development and fielding of a site characterization and analysis penetrometer system, a system used for site characterization in the DoD's cleanup program. Each organization has a defined area of responsibility, thereby maximizing use of limited funds for addressing common DoD cleanup problems. A joint program under SERDP has also been initiated with EPA and DOE in development of a groundwater modeling system for contaminated site cleanup.

The Army, as lead agency for DoD, is working with EPA on biodiversity research through a Biodiversity Research Consortium. Results of this cooperative effort will allow DoD to optimize its biodiversity research, thereby enhancing its capability to manage biodiversity on DoD sites in a bioregional and national context.

The Army cooperates on a smaller scale with other U.S. government agencies to accomplish a mutual goal or to share a unique capability. These agencies include the Departments of Health and Human Services, Energy, Labor, and Education, and the National Oceanic and Atmospheric Administration, the Food and Drug Administration, and the U.S. Geological Survey.

5. Army Efforts With Industry

Army technology can help produce a stronger civilian economy in partnership with U.S. industry, bringing new products and processes to the marketplace.

a. National Automotive Center

Recognizing the many dual-use benefits available in cooperation with industry, academia, and government, the Army established NAC in 1993. The NAC, located at the U.S. Army TARDEC, Warren, Michigan, serves to accelerate the development of dual-use automotive technologies. Through BAAs, the NAC leverages commercial R&D projects that have potential military applications. The NAC also interfaces

with the United States Council for Automotive Research and automotive vendors, suppliers, and small businesses to identify areas of potential collaboration with the automotive industry.

b. National Rotorcraft Technology Center

The NRTC, established in 1996, is a catalyst for facilitating collaborative rotorcraft research and development among the DoD (Army and Navy), NASA, the Federal Aviation Administration, industry, and academia. It serves as the means to cooperatively develop and implement a rotorcraft technology plan and national strategy that can effectively address both civil and military rotorcraft needs.

The NRTC includes industry and academia as partners in the Rotorcraft Industry Technology Association (RITA), a nonprofit corporation that focuses on developing rotorcraft design, engineering and manufacturing technologies, and shares technology among its members.

E. INTERNATIONAL TECHNOLOGY LEVERAGING

In the light of the shrinking defense budgets in the post-cold-war era and the coalition approach to resolving international conflicts, participation in international cooperative R&D in key technology areas is becoming increasingly important. These efforts offer high-payoff opportunities for leveraging U.S. investments in technology development with those of our international partners and for helping to build the political relationships required for coalition operations. Such leverage will help maintain U.S. technological advantage, stimulate battlefield interoperability, and, through subsequent codevelopment of advanced dual-use technology products, sustain our economic competitiveness. Cooperative R&D offers the U.S. Army a means of remaining oriented to future and next-generation needs and of continuing to learn about new ideas and new approaches.

1. International Cooperation Policy

Secretary of Defense Cohen, in his memorandum of 23 March 1997, called for maximum utilization of International Armaments Cooperation:

> *International Armaments Cooperation is a key component of the Department of Defense bridge to the 21st Century. In the evolving environment of coalition warfare, limited resources, and a global industrial and technology base, it is DoD policy that we utilize International Armaments Cooperation to the maximum extent feasible, consistent with sound business practice and with the overall political, economic, technological and national security goals of the United States.*

The Deputy Undersecretary of the Army (International Affairs) (DUSA(IA)) is responsible for formulating all international programs and policy consistent with national security objectives and policies established by the President or the Secretary of Defense. The DUSA(IA) has identified the *Army Science and Technology Master Plan* (ASTMP) and specifically Volume II, Annex E, as the normative guidance for determining the existence of an acceptable quid pro quo for international technology-based cooperation. AMC has the responsibility for executing international agreements to implement technology leveraging as it applies to AMC business areas.

Annex E provides policy guidance for determining appropriate areas for the initiation of discussions for possible new cooperative agreements in identified technology areas. The proponent organization must make the final determination that an appropriate quid pro quo exists for concluding cooperative agreements. Annex E is a snapshot in time, and new and rapidly emerging developments may not be reflected therein. As this document is suitable for public release, sensitive or classified information is not included.

The mechanisms for international cooperation, specific technology leveraging opportunities, and future trends are discussed below. The leveraging opportunities identified in Annex E and summarized here correspond with those in

Chapter IV for implementation in the near to mid term (2 to 6 years) with Chapter V for areas offering longer term promise. As part of the 1998 ASTMP update process, we evaluated how research capabilities are evolving to support a potential for international cooperation in the ASTMP technology areas. The trends found, summarized in Figure VII–6, are clear. Over the next decade we will see increased opportunities for cooperation with a growing number of countries in areas of direct interest to the U.S. Army.

2. International Cooperation

The Army's strategic goal in international cooperation is to promote technology leveraging—activities that multiply the effects of U.S. investment in technology by taking advantage of the investments and capabilities of others.

Programs can range from cooperation in basic S&T, through codevelopment and foreign weapons T&E, to coproduction, foreign sales, and downstream logistics support. Most international programs are focused on exploratory development and the earliest stages of advanced development. We also support small research "seed" contracts with world-class researchers and maintain research offices in London and Tokyo.

Our strategy encourages partnering with our allies to ensure that our programs incorporate the best available technology worldwide. Leveraging the technology investments that we make with those made by our allies eliminates duplication of effort and ensures the best technology at the lowest cost to the Army. We use a combination of techniques and methods that are shown as the building blocks of international cooperation in Figure VII–7.

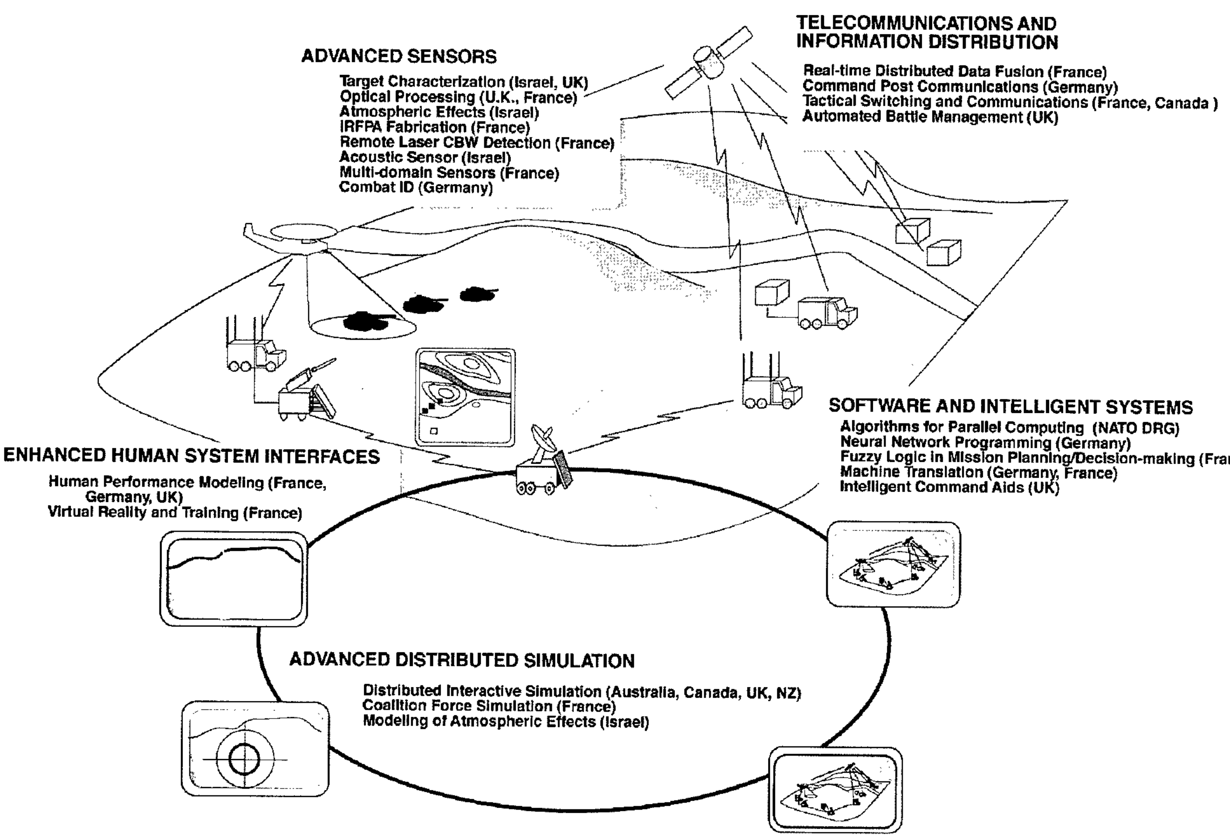


Figure VII–6. Trends in Opportunities for International Technology Leveraging

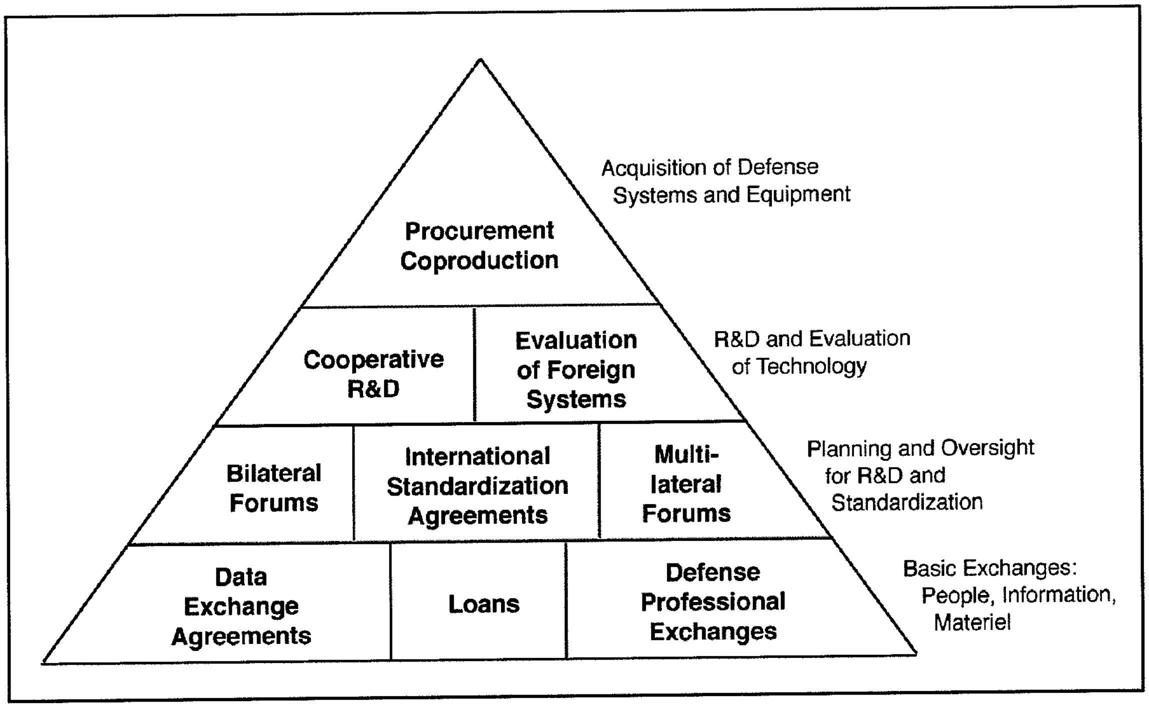


Figure VII–7. Building Blocks of International Cooperation

The foundations of international cooperation are the exchange of information, loans of materiel, and the exchange of defense professionals, primarily scientists and engineers. This fundamental level of cooperation is the base of the triangle. Information and data are exchanged under the Defense Data Exchange Program, in which the Army participates in information exchanges with more than 25 countries in more than 250 technologies. The Army also exchanges defense professionals with allies to work onsite on common technical problems and opportunities. These exchanges occur through the International Professional Exchange Program and the short-term Abbreviated Professional Exchange Program, and, informally, through visits and interactions at technical symposia, conferences, and meetings.

At the next level, international cooperation is facilitated by S&T forums (bilateral and multilateral) that foster and coordinate international cooperative activities. Two such forums are bilateral Technology Working Groups with Israel and France, which provide for senior management oversight of cooperative R&D activities. Other activities at this level include the multilateral forums of The Technology Cooperation Program, whose members include Australia, Canada, New Zealand, the United Kingdom, and the United States; and the NATO Research Technology Organization and Standardization Groups. Such forums provide management oversight and direction to individual technical experts participating in international exchange programs.

International cooperation at a level beyond information exchange (such as exchanges of equipment and laboratory samples, or codevelopment of hardware and software) generally takes place through cooperative R&D programs executed under an MOA that spells out terms, conditions, and commitments of the United States and the partner country in pursuing agreed-to R&D objectives. A recently implemented variation of a traditional focused MOU is the Technology Research and Development Program, also known as an umbrella MOA. This type of MOA, which has been implemented with the United Kingdom, France, Germany, Canada, Israel, and South Korea, allows for project annexes in specific areas of R&D cooperation and

reduces the need and time required for renegotiating common elements of all MOAs (e.g., intellectual property rights) with a given ally.

In an effort to leverage all domestic and international resources, the Army has joined with other government agencies to pool talents and resources on high-payoff cooperative R&D projects where there are common interests and requirements. One such program is the U.S. India Fund run by the Department of State. This program is designed to promote basic research with Indian universities and government facilities. Another program, the NATO Cooperative R&D program, has been expanded to include the non-NATO allies of Korea, Japan, Israel, Egypt, and Australia. This program is also known as the Nunn program after the original amendment to the FY86 DoD Authorization Act, sponsored by then Senator Sam Nunn.

Proposed Nunn-funded projects address key Army technologies (both conventional Army defense and dual use) that respond to areas of significant interest to our allies and where a joint approach (with our allies) is deemed critical. Funding for these projects remains dependent on the DoD-wide approval and agreement process.

The Foreign Comparative Test Program provides funding to determine whether foreign systems satisfy U.S. Army requirements. Our strategy for international cooperation also includes coproduction and procurement of systems, with the ultimate goal of standardization and interoperability of equipment.

3. Army International Organizations

a. Deputy Under Secretary of the Army for International Affairs

To streamline Army international cooperative programs, DUSA(IA) was formed in 1996. All policy functions from the Secretary of the Army (Research, Development, and Acquisition (SA(RDA)), the Deputy Chief of Staff for Operations and Plans (DCSOPS), the Deputy Chief of Staff for Logistics (DCSLOG), and AMC were brought together and provided the Army with a more unified coordinated international policy and approach for international activities. General Order 10 (12 August 1997) delineates the specific authorities and responsibilities of DUSA(IA).

DUSA(IA) develops and promulgates policy, and AMC and TRADOC execute that policy. AMC continues to oversee development and execution of international agreements (IAs) for materiel development to leverage global technology and to feed multinational force compatibility (MFC). Major subordinate commands (MSCs) support bilateral forums such as technology working groups and multilateral forums such as the NATO Research Technology Organization. TRADOC manages the development of coalition doctrine through such forums as Army-to-Army Staff Talks, along with participation in NATO forums designed to promote MFC and lay the foundation that will enable the Army to fight effectively with our allies.

b. U.S. Army Materiel Command, International Cooperative Programs Activity

The AMC International Cooperative Programs Activity (ICPA) is chartered to develop and execute IAs for AMC-managed technology. This includes the full range of international agreements as described earlier. The ICPA also acts as the Army's Office of Record for all implemented IAs. Each AMC MSC has an international office that acts as the local advocate for the initiation, execution, and management of IAs.

Recognizing the need to increase leverage of global technology, the ICPA has initiated an IA improvement program to streamline the IA approval process to better utilize shrinking resources. This uses integrated product teams to reduce redundant staffing and the international agreements tracking systems (IATS), which provides a centralized electronic database. The IATS gives the Army total visibility on all proposed and existing international agreements. With the Army's new "single voice approach" through the DUSA(IA) and AMC's IA improvement pro-

gram, the staffing and disposition of international agreements will be greatly streamlined.

4. Opportunities

The Army assesses international opportunities across a broad spectrum of areas on a continuing basis. Subjects addressed recently include artificial intelligence, antiarmor technology, autonomous guidance, microelectronics, computing and simulation, aerospace propulsion, biotechnology, virtual reality, photonics, robotic sensors, materials and structures, and military power sources. Leveraging opportunities are continually identified through individual scientists' and engineers' recommendations, based on their direct interactions with foreign counterparts.

Table VII–1 highlights the breadth of leveraging opportunities discussed in greater depth in Annex E. This table also provides a crosswalk between the basic research topics (Chapter V) and technologies (Chapter IV). The arrows indicate a rough qualitative assessment of those areas where the individual tables contained in Annex E identify a critical mass of foreign basic and applied research capabilities. As noted previously, the numerous overlaps evident in the crosswalk are indicative of a growing depth of infrastructure combining where both basic and applied efforts offer potential for long-term, sustained cooperation. Finally, the arrows give a qualitative feel for the quality of the research capability and key trends as shown in the legend to the table.

Accessing foreign technology in compliance with legal and security requirements through cooperative programs requires international agreements. These legal vehicles allow the bench scientists and engineers access to foreign technology covered by the scope of such agreements to address R&D requirements. Annex E further describes technology leveraging opportunities while providing Army points of contact through which further details can be obtained. Figure VII–8 illustrates how these technology leveraging opportunities could impact major Army systems.

5. Army Digitization Program

Digitization of the battlefield has emerged as a major thrust of U.S. national military planning. The Army Digitization Master Plan calls for the development of systems to achieve a tactical C^3I system that will significantly enhance situation awareness, force integration, combat identification and target hand-off, database distribution, and communications. The international digitization strategy provides the framework for international cooperation to enhance interoperability and technology leveraging. In the mid and far terms, international cooperative programs will enhance capabilities with reduced technical risk by ensuring the Army access to advanced technologies and alternative approaches.

Worldwide technology trends and specific C^4I technology leveraging opportunities have been identified in the Army Digitization Master Plan and the international digitization strategy. Opportunities include:

- Advanced displays and interactive displays, particularly enhanced human interfaces to support improved operator effectiveness.
- Software and intelligent systems, particularly in language understanding/ translation, and intelligent agents; sensed and stored data and seamless interaction with human operators, and autonomous systems.
- Telecommunications and information distribution with emphasis on wireless digital data limits to provide secure, robust, real-time interchange of data between dispersed and highly mobile force elements.
- Advanced distributed simulation of synthetic environments and automated forces and operations to allow distributed modeling and rehearsal to support mission planning and force optimization.

Table VII–1. International Opportunities Summary

Technology Areas	Basic Research Areas											
	Mathematical Sciences	Computer and Information Systems	Physics	Chemistry	Materials Science	Electronics Research	Mechanical Sciences	Atmospheric Sciences	Terrestrial Sciences	Medical Research	Biological Sciences	Behavioral, Cognitive, and Neural Sciences
Aerospace Propulsion and Power	►			►	►		▲					
Air Platforms	►		▲	►	►	▲	▲					▲
Nuclear, Biological, and Chemical Defense			△	►		▷	▷	▷		▲	▲	
Individual Survivability and Sustainability				►	▲	△	△			▲	▲	▲
Command, Control, and Communications	▷	▲	△			▲						▲
Computing and Software	△	▷	▲			▷						▲
Conventional Weapons	△		△	►	►	△	▲					
Electronic Devices			▲		►	▲					△	
Electronic Warfare/Directed-Energy Weapons			△	△		△	△	△				
Civil Engineering and Environmental Quality			▲	△	►	▷		▷	►		▲	
Battlespace Environments	▷	▷	▲			►		►	►			▷
Human Systems Interfaces	△	▲	▷			▷						▲
Manpower, Personnel, and Structures		△										▲
Materials, Processes, and Structures	△	△		►	►		▲				▲	
Medical and Biomedical Science and Technology		△								▲	▲	
Sensors	▷	▷	▲	▷	►	△		►	►			▷
Ground Vehicles		▷	▷	►	►	►	▲		▷			
Manufacturing Science and Technology	▷	▷			▲		▲				▲	
Modeling and Simulation	△	△	▷				△	▷	▷			▲

One or more countries offer:

■ Filled-in arrowhead indicates breadth and depth in applied AND basic research

□ Open arrowhead indicates specific niches in applied OR basic research

Direction of arrowhead indicates potential of the identified capabilities to advance state-of-the-art

△ Support for potential significant breakthrough

▷ Support for continued evolutionary advances

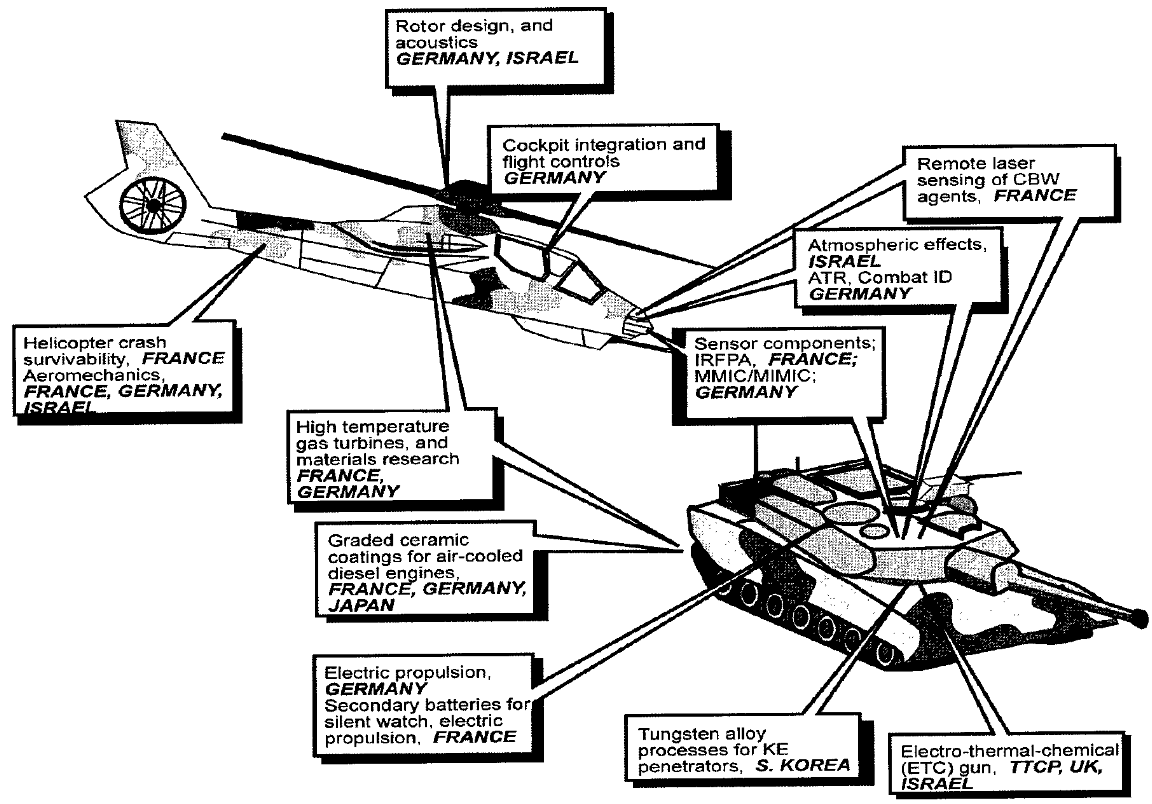


Figure VII–8. Impact of Leveraging on Army Systems

- Advanced sensors, particularly multi-domain smart sensors for continuous, rapid, and precise discrimination and targeting of all threats under all anticipated battlefield conditions.

ARL's federated laboratory provides new dynamic avenues for government-to-government relationships with enhanced opportunities for technology leveraging through industry-to-industry and academia-to-academia teaming arrangements.

6. Future Trends

Technology is a valuable global commodity. As discussed earlier, access to technology to support Army programs is complementary to the mid- and far-term ASTMP milestones. There are world-class capabilities in virtually all the ASTMP research and technology areas (Chapters IV and V) outside U.S. borders. The European community will continue to provide a significant capability in most of the Army's research and technology areas of interest. Similar trends are shown for Japan and to a lesser degree for Canada, Israel, and Sweden. A more limited contribution is indicated for other allies and the Former Soviet Union. Many countries have niches of excellence in specific areas of technology or basic research. Annex E identifies 37 countries with scientific or technological capabilities of interest to the U.S. Army.

7. Summary

The benefits of international cooperation are well known and documented. Some are highly concrete (e.g., significant savings in time and cost). Others—improved interoperability, acquisition of information helpful to U.S. programs, and greater opportunity for contacts with researchers with new ideas and approaches to problems—are less quantifiable but no less valuable. By taking the following steps, the

Army will enhance its ability to leverage global technology:

- Identifying critical information and communications technology opportunities through worldwide technology assessments.
- Encouraging industry-to-industry/academia teaming arrangements that allow the leveraging of allied commercial research and technology.
- Utilizing existing agreements and forums when possible to exchange research and technology information and to develop specific new initiatives.
- Developing new and innovative ways to leverage perishable global technology in a timely fashion.

With the formation of the DUSA(IA) for policy development and the empowering of AMC to execute international agreements, the Army has taken major strides toward unifying and simplifying working with our allies. Given our shrinking resources, it is more important than ever to leverage research and technology if we are to maintain our qualitative edge over potential adversaries in the future.

ABBREVIATIONS

ABBREVIATIONS

21 CLW	21st century Land Warrior
2D	two dimensional
3D	three dimensional
3rd GARD	third-generation advanced rotor demonstration
4D	four dimensional
4thID	4th Infantry Division

A

A/D	analog to digital
A^2C^2S	Army airborne command and control system
AAAV	advanced amphibious assault vehicle
AAE	Army Acquisition Executive
AAN	*Army After Next*
AAR	after-action review
ABCS	Army battle command system
ACAT	acquisition category
ACE	Army Corps of Engineers
ACOM	Atlantic Command
ACPLA	agent containing particles per liter of air
ACR	advanced concept and requirements
ACT II	Advanced Concepts and Technology II
ACTD	Advanced Concept Technology Demonstration
ACTS	advanced communication technology satellite
ADAS	air-deployable acoustic sensor
ADCSOPS(FD)	Assistant Deputy Chief of Staff for Operations (Force Development)
ADS	advanced distributed simulation
ADTP	Army Technology Demonstration Plan
ADTT	Army Domestic Technology Transfer
ADVOX	advanced oxidation
AEC	airborne electronic combat
AFAS	Advanced Field Artillery System
AFATDS	Advanced Field Artillery Tactical Data System
AGCCS	Army global command and control systems
AGES	air/ground engagement simulation
AH	automated howitzer
AHP	advanced helicopter pilotage
AHPCRC	Army High-Performance Computing Research Center
AI	artificial intelligence
AIAA	American Institute of Aeronautics and Astronautics
AIDS	Acquired Immune Deficiency Syndrome
AIMS	advanced integrated manportable system
AIN	Army interoperability network
AIS	autonomous intelligent submunition
AiTRAP	aided target recognizer and processor
ALERT	air/land enhanced reconnaissance and targeting
AllWx	all weather
ALON	aluminum oxynitride
ALTUS	unmanned aerial vehicle
AMBL	Air Maneuver Battle Laboratory
AMC	Army Material Command
AMCOM	Aviation and Missile Command
AMEDD C&S	Army Medical Department Center and School
AMG	Architecture Management Group
AMP	*Army Modernization Plan*
AMRAAM	advanced medium-range air-to-air missile
AMSAA	Army Materiel Systems Analysis Agency
AMSEC	Army Modeling and Simulation Executive Committee
AMSGOSC	Army Model and Simulation General Officer Steering Committee
AMS–H	advanced missile system—heavy
AMSO	Army Modeling and Simulation Office
AMSUS	Association of Military Surgeons of the United States
AMTEC	alkali metal thermal-electric converter
AMUST	airborne manned/unmanned system technology
ANSUR	anthropometric survey
AOA	angle of attack
AP	active protection
APG	Aberdeen Proving Ground
APOE	aerial port of embarkation
APS	active protective system
ARC	Advanced Research Center; Ames Research Center; advanced rotor concepts
ARCAT	advanced rotorcraft aeromechanics technologies
ARDEC	Armaments Research, Development, and Engineering Center
ARI	Army Research Institute for the Behavioral and Social Sciences
ARL	Army Research Laboratory
ARM	antiradiation missile
ARNG	Army National Guard
ARO	Army Research Office
ART	advanced rotorcraft transmission
ASA(RDA)	Assistant Secretary of the Army (Research, Development, and Acquisition)
ASAS	all-source analysis system
ASB	Army Science Board

ASBREM	Armed Services Biomedical Research Evaluation and Management
ASE	airborne survivability equipment
ASHPC	advanced simulation and high-performance computing
ASM	armored systems modernization
ASME	American Society of Mechanical Engineers
ASPO	Army Space Program Office
ASRT	autonomous scout rotorcraft testbed
ASSH	aircraft system self-healing
ASSTC	advanced surgical suite for trauma casualties
ASTAG	Army Science and Technology Advisory Group
ASTIS	Army Software Technology Investment Strategy
ASTMIS	Army Science and Technology Management Information System
ASTMP	*Army Science and Technology Master Plan*
ASTWG	Army Science and Technology Working Group
ATA	Army Technical Architecture
ATACMS	Army tactical missile system
ATD	Advanced Technology Demonstration
ATDMP	Advanced Technology Demonstration Management Plan
ATG	air to ground
ATGM	antitank guided missile
ATGW	antitank guided weapon
ATM	asynchronous transfer mode; asynchronous transmission mode
ATN	advanced tactical navigator
ATR	automatic target recognition
AWE	advanced warfighting experiment

B

B^2C^2	battalion and below command and control
B&P	bid and proposal
BAA	Broad Agency Announcement
BAS	battlefield automated system
BAST	Board on Army Science and Technology (National Research Council)
BAT	brilliant antitank
BAWS	biological aerosol warning system
BBS	bulletin board service
BC^2	battlespace command and control
BCDMA	broadband code division multiple access
BCDSS	battle command decision support system
BCID	battlefield combat identification
BCIS	battlefield combat identification system
BCNS	behavioral, cognitive, and neural sciences
BCT	brigade combat team
BCTP	battle command training program
BDA	battle damage assessment
BDE	brigade
BDS	battlefield distributed simulation
BDS–D	battlefield distributed simulation—developmental
BES	Budget Estimate Submission
BFA	battlefield function area
BFM	battlescale forecast model
BHAW	brilliant helicopter advanced weapons
BIS	battlespace information system
B–ISDN	broadband integrated services digital network
BITS	battlefield information transmission system
BL4	biosafety level 4
BLITCD	Battle Laboratory Integration, Technology, and Concepts Directorate
BM	battle management
BMAR	backlog of maintenance and repair
BMC	Battlefield Manufacturing Center
BMC^4I	battle management command, control, communications, computers, and intelligence
BMD	ballistic missile defense
BMDO	Ballistic Missile Defense Organization
BOA	battlefield ordnance awareness
BOD	board of directors
BOM	bit oriented message
BOS	battlefield operating system
BRAC	base realignment and closure
BRAT	beyond line-of-sight reporting and tracking
BRDF	bidirectional reflectance distribution function
BRP	*Basic Research Plan*
BSFC	brake specific fuel consumption
BSFV–E	Bradley Stinger fighting vehicle—enhanced
BW	biological warfare; bandwidth
BWCDK	biological warfare agent confirmation diagnostic kit

C

C	Centigrade
C^2	command and control
C^2I	command, control, and intelligence
C^2TL	commercial communications technology testbed
C^2V	command and control vehicle
C^2W	command and control warfare
C^3	command, control, and communications
C^3I	command, control, communications, and intelligence
C^3IEW	command, control, communications, intelligence, and electronic warfare
C^4	command, control, communications, and computers
C^4I	command, control, communications, computers, and intelligence
cm	centimeter
CAA	Concepts Analysis Agency
CAAM	computer-assisted artillery meteorological
CAC^2	combined arms command and control

CAD	computer-aided design
CAE	computer-aided engineering
CAFT	Center for Advanced Food Technology
CAGES	common air/ground electronic combat suite
CAM	computer-aided manufacturing; computer-aided modeling
CAPS	counteractive projection system
CARC	chemical agent resistant coating
CARS	contingency airborne reconnaissance system
CATOX	catalytic oxidation
CATS	combined arms training strategy
CATT	combined arms tactical trainer
CAV	composite armored vehicle
CB	chemical and biological
CBD	chemical and biological defense
CBDCOM	Chemical and Biological Defense Command
CBTDEV	combat development
CBW	chemical and biological warfare
CCAWS	close combat antiarmor weapon system
CCD	camouflage, concealment, and deception
CCS	close combat support
CCTT	close combat tactical trainer
CD	counterdrug
CD–ROM	compact disk—read-only memory
CDA	commanders decision aid
CDMA	code division multiple access
CE	chemical energy
CECOM	Communications–Electronics Command
CENTCOM	Central Command
CEP	circular error probable
CERDEC	Communications–Electronics Research, Development, and Engineering Center
CERL	Construction Engineering Research Laboratory
CFD	computational fluid dynamics
CG	commanding general
CGF	computer-generated forces
CHLS	combat health logistics system
CHPR	Cooper Harper Pilot's Rating
CHS	combat health support
CI	counterintelligence
CIFER	comprehensive identification from frequency responses
CINC	commander in chief
CKEM	compact kinetic-energy missile
CM	countermine; countermeasures
CMC/CC	ceramic matrix composites/carbon composites
CMMS	conceptual models of mission space
CMOS	complementary metal oxide semi-conductor
CMRL	counter multiple rocket launcher
CMTC	Combat Maneuver Training Center
CNI	communications, navigation, identification
CNR	combat net radio
COA	course of action
COBRA	collection of broadcasts from remote assets
COC	Council of Colonels
COE	center of excellence; combat operating environment
COMINT	communications intelligence
COMSEC	communications security
CONOPS	continuous operations
CONSCAN	conical scan
CONUS	continental United States
COTS	commercial off the shelf
CP	collective protection; command post
CPAR	construction productivity advancement research
CRDA	cooperative research and development agreement
CRREL	Cold Regions Research and Engineering Laboratory
CS	combat support
CS/TMBS	crew station/turret motion base simulator
CSA	Chief of Staff, Army
CSC	combat stress control
CSRDF	Crew-Station Research and Development Facility
CSS	combat services support
CSSCS	combat service support control systems
CTC	combat training center
CTIN	Counterdrug Technology Information Network
CW	chemical warfare
CWAR	continuous wave acquisition radar

D

D/NAPS	day/night, adverse-weather pilotage system
dB	decibel
decon	decontamination
DA	Department of the Army
DAMA	demand assignment multiple access
DARPA	Defense Advanced Research Projects Agency
DAPKL	diode-array pumped kilowatt laser
DAS(R&T)	Deputy Assistant Secretary for Research and Technology
DAS	data acquisition segment
DB	database
DBC	digital battlefield communications
DBMS	database management system
DBS	direct broadcast satellite
DBSBL	dismounted battlespace battle laboratories
DC	distributed center
DCD	director of combat developments
DCSCD	Deputy Chief of Staff for Combat Developments
DCSLOG	Deputy Chief of Staff for Logistics
DCSRDA	Deputy Chief of Staff for Research, Development, and Acquisition

DCSOPS	Deputy Chief of Staff for Operations and Plans
DDL	direct downlink
DDR&E	Director, Defense Research and Engineering
DDS	direct digital synthesizer
DE	directed energy
DEA	Drug Enforcement Agency
DEC	Digital Equipment Corporation
DEM/VAL	demonstration and validation
DENS	directed-energy neutralization system
DET	dynamic environment and terrain
DEW	directed-energy weapon
DF	direction finder
DI&S	design integration and supportability
DIL	Digital Integrated Laboratory
DIS	distributed interactive simulation, data integration segment
DISN	distributed interactive simulation network
DLC	diamond-like carbon
DMSO	Defense Modeling and Simulation Office
DNA	Defense Nuclear Agency
DNA	deoxyribonucleic acid
DoD	Department of Defense
DoE	Department of Energy
DOE	diffractive optical element
DOF	degrees of freedom
DOJ	Department of Justice
DRE	ducted rocket engine
DREN	Defense Research and Engineering Network
DS2	decontamination solution 2
DSA	depth and simultaneous attack
DSB	Defense Science Board
DSCS	Defense Satellite Communications System
DSI	defense simulation internet
DSP	digital signal processor
DSSA	domain-specific software architecture
DSTAG	Defense Science and Technology Advisory Group
DSWA	Defense Special Weapons Agency
DTAP	*Defense Technology Area Plan*
DTED	digital terrain elevation data
DTIC	Defense Technical Information Center
DTLOMS	doctrine, training, leader development, organization, materiel, and soldier
DTO	Defense Technology Objective
DTSS	digital topographic support system
DU	depleted uranium
DUAP	Dual-Use Applications Program
DUSA(IA)	Deputy Under Secretary of the Army (International Affairs)
DUSA(OR)	Deputy Under Secretary of the Army (Operations Research)
DUSD(AT)	Deputy Under Secretary of Defense for Advanced Technology

E

EA	electronic attack
EAD	echelons above division
EADSIM	extended air defense simulation
EADTB	extended air defense testbed
EARC	Electric Armaments Research Center
EBF	electronic battlefield
ECCM	electronic counter-countermeasures
ECM	electronic countermeasures
ECOG	Electronics Coordinating Group
ECP	engineering change proposal
EEI	essential elements of information
EELS	early entry, lethality, and survivability
E-FOG	enhanced fiber optic guided
EFOGM	enhanced fiber optic guided missile
EFP	explosively formed projectile
EHF	extremely high frequency
ELINT	electronic intelligence
EM	electromagnetic
EMD	engineering and manufacturing development
EME	electromagnetic environment
EMI	electromagnetic interference
EMW	engineer and mine warfare
EO	electro-optic; electro-optical
EOCM	electro-optical countermeasures
EPA	Environmental Protection Agency
EPP	extended planning period
EPW	enemy prisoner of war
ERA	extended range artillery
ERDEC	Edgewood Research, Development, and Engineering Center
ES	electronic support
ESA	electronic safe and arm
ESS	electrostatic sensor
ET	embedded training
ETC	electrothermal-chemical
ETEC	enterotoxigenic *Escherichia coli*
ETRAC	enhanced tactical radar correlator
EUCOM	European Command
EUT	early user test
EV–II	Eagle Vision II
EW	electronic warfare
EXCIMS	Executive Council for Modeling and Simulation
EXFOR	experimental force

F

F	Fahrenheit
FAA	Federal Aviation Administration
FAAD	forward area air defense
FACE	forward aviation combat engineering
FAMSIM	family of simulations
FARV	future armored resupply vehicle
$FBCB^2$	Force XXI battle command brigade and below
FCR	fire control radar
FCS	flight control system; future combat system; fire control system

FDA	Food and Drug Administration
FDDT	forward deployable diagnostic test
FDR	future digital radio
FFRDC	federally funded research and development center
FI/LTL	flame incendiary/less than lethal
FIR	far infrared
FIV	future infantry vehicle
FLIR	forward-looking infrared
FLOT	forward line of troops
FMTI	future missile technology integration
FMTV	family of medium tactical vehicles
FOC	future operational capability
FOGM	fiber optic guided missile
FOPEN	foliage penetration
FORSCOM	forces command
FOTT	follow-on to TOW
FOV	field of view
FPA	focal plane array
FSAP	full spectrum active protection
FSB	forward support battalion
FSCS	future scout and cavalry system
FTX	field training exercise
FUE	first unit equipped
FXXI LW	Force XXI Land Warrior
FY	fiscal year
FYDP	Future-Years Defense Plan

G

g	acceleration of gravity
gflops	10^9 floating point operations per second
G	gravitational constant
G&C	guidance and control
GaAs	gallium arsenide
GaN	gallium nitride
GaSb	gallium antimony
GASCO	generic algorithm for cockpit optimization
Gb	gigabyte
GB	Grenadier BRAT
GBCS	ground-based common sensor
GBps	gigabytes per second
GBR	ground-based radar
GBS	ground-based sensor
GCCS	Global Command and Control System
GCS	ground control station
GCSS	Global Combat Support System
GHz	gigahertz
GIF	guidance integrated fuze
GIS	geographic information system
GOTS	government off the shelf
GPEN	ground penetration
GPR	ground penetrating radar
GPS	global positioning system
GSD	graphical situation display
GTG	ground to ground
GVW	gross vehicle weight
GW	gross weight

H

Hz	hertz
HACT	helicopter active control technology
HBCU	historically black colleges and universities
HCI	hydrocynamic acid
HCTR	high capacity trunk radio
HEAT	high explosive antitank
HF	high frequency
HIMARS	high mobility rocket system
HITL	hardware in the loop
HIV	human immunodeficiency virus
HLA	high level architecture
HMD	helmet-mounted display
HMGL	high mobility ground launched
HMMWV	high mobility, multipurpose wheeled vehicle
HMPT	human factors, manpower, personnel, and training
HPC	high-performance computing
HPM	high power microwave
HPRF	high power radio frequency
HRED	Human Research and Engineering Directorate
HTI	horizontal technology integration
HUMINT	human intelligence
HV	hypervelocity

I

I/O	input/output
I^2	image intensification
I^2R	imaging infrared
InP	indium phosphide
Intel	intelligence
IA	international agreement
IAS	integrated acoustic system
IATS	international agreements tracking system
IBACS	integrated battlefield area communications system
IBAD	ion beam assisted deposition
IBM	International Business Machines
IC	integrated circuit
ICH	improved cargo helicopter
ICM	integrated countermeasures
ICPA	International Cooperative Program Activity
ICT	integrated concepts team
ID	identification
ID&PE	information display and performance enhancement
IDREN	Interim Defense Research and Engineering Network
IEC	Integration and Evaluation Center
IEEE	Institute of Electrical and Electronic Engineers
IEW	intelligence and electronic warfare
IEWCS	intelligence and electronic warfare countermeasures suite

IFF	identification friend or foe
IFFC	integrated fire and flight control
IFOG	interferometric fiber-optic gyroscopes
IHPTET	integration high performance turbine engine technology
IIT	integrated idea team
ILIR	in-house laboratory independent research
ILS	integrated logistics support
IMETS	integrated meteorological system
IMF	intelligent minefield
IMINT	imagery intelligence
IMO	International Mathematical Olympiad
IMPACT	integrated maintenance management prioritization analysis and coordination tool
IMPRINT	integrated MANPRINT tools
IMU	inertial measurement unit
INFOSEC	information security
INS	inertial navigation system
IOC^2	information operations command and control
IP	Internet protocol
IPB	intelligence preparation of the battlefield
IPE	integrated platform electronics
I–PORT	individual soldier portable
IPPD	integrated product and process development
IPT	integrated product team
IR	infrared
IR&D	independent research and development
IRCM	infrared countermeasures
IREMBASS	Improved Remotely Monitored Battlefield Sensor System
IRFPA	infrared focal plane array
IS	intelligent system
IS&T	information science and technology
ISAR	interferometric synthetic aperture radar
ISAT	integrated sensors and targeting
ISDN	integrated services digital network
ISEF	International Science and Engineering Fair
ISR	intelligence, surveillance, and reconnaissance
ISS	individual survivability and sustainability
IST	information systems and technology
ISTD	Information Sciences and Technology Directorate
ITEMS	interactive tactical environment management system
IUSS	integrated undersea surveillance system; individual unit soldier simulation
IW	information warfare

J

J/S	jamming/signal
JBPDS	joint biological point detection system
JBREWS	joint biological remote early warning system
JBUDS	joint biological universal detection system
JCM	joint conflict model
JCS	Joint Chiefs of Staff
JFLCC	Joint Force Land Component Commander
JLINK	Janus linked to DIS
JPMO	Joint Program Management Office
JPO	Joint Project Office
JPS	joint precision strike
JPSD	Joint Precision Strike Demonstration
JRTC	Joint Readiness Training Center
JSAM	joint service aviation mask
JSAWM	joint service agent water monitor
JSCBD	joint service chemical and biological decontaminants
JSGPM	joint service general purpose mask
JSHS	Junior Science and Humanities Symposium
JSLIST	joint service lightweight integrated suit technology
JSNBCRS	joint service nuclear, biological, and chemical reconnaissance system
JSSAMP	*Joint Service Small Arms Master Plan*
JSWILD	joint service warning and identification LIDAR detector
JTAGG	joint turbine advanced gas generator
JTAGS	joint tactical ground station
JTR	joint transport rotorcraft
JVAP	Joint Vaccine Acquisition Program
JWARN	joint warning and reporting network
JWC	joint warfighting capabilities
JWID	Joint Warfighter Interoperability Demonstration
JWSTP	*Joint Warfighter Science and Technology Plan*
kg	kilogram

K

kj	kilojoule
km	kilometer
km/s	kilometer per second
kw	kilowatt
KE	kinetic energy
KEW	kinetic energy weapons
KMR	Kwajalein Missile Range
L/V	lethality/vulnerability

L

lb	pound
Li	lithium
LAD	logistics anchor desk
LADAR	laser radar
LAH	lightweight automated howitzer
LAN	local area network
LaRC	Langley Research Center
LASERCOM	laser communications
LCLO	low cost, low observable
LCP	liquid crystal polymer
LCPK	low-cost precision kill
LCSEC	life-cycle software engineering center
LeRC	Lewis Research Center
LH	light helicopter

LIC	low-intensity conflict
LIDAR	light detection and ranging
LIGHTSAT	small lightweight satellite
LOAL	lock on after launch
LOC	line of communications
LOSAT	line-of-sight antitank
LOTSOS	logistics over-the-shore operational simulator
LPD	low probability of detection
LPI	low probability of interception
LQI	Laboratory Quality Initiative
$LRAS^3$	long-range advanced scout surveillance system
LRIP	low rate initial production
LS	line scanner
LSTAT	life support for trauma and transport
LT2	light tactical operation center testbed
LW	Land Warrior
LWIR	long wave infrared

M

m/s	meter per second
m	meter
met	meteorological
mm	millimeter
M&R	maintenance and repair
M&S	modeling and simulation
MANPRINT	manpower and personnel integration
MANTECH	manufacturing technology
MASINT	measurement and signal intelligence
MAT	multimode airframe technology
MATDEV	materiel developer
MATES	manufacturing and tooling expert system
MBMMR	multiband multimode radio
MBps	million bytes per second
MCBDRP	Medical Chemical and Biological Defense Research Program
MCS	maneuver control system
MCT	MOS controlled thyrister; mercury cadmium telluride
MD	manufacturing demonstration
MDA	Milestone Decision Authority
MDS	modular design system
MECOG	Mechanics Coordinating Group
MELIOS	mini eye-safe laser infrared observation set
MEM	microelectromechanics
MEMS	microelectrochemical system
MEP	mission equipment package
MERC	mobility enhancing ration component
MERCURY	(a model system of environmental hazards)
METT–T	mission, enemy, troops, terrain, and time
MFC	multinational force compatibility
MFOM	MLRS family of submunitions
MFS^3	multifunction staring sensor suite
MGR	moving target indicator ground radar
MH/K	mine hunter-killer
MHz	megahertz
MI	minority institution
MICOM	Missile Command
MIDAS	man–manchine integration design and analysis system
MILES	multiple integrated laser engagement system
MJ	megajoules
MLRS	multiple launch rocket system
MLS	multilevel security
MMIC	monolithic microwave integrated circuit
MMS	meteorological measuring set
MMW	millimeter wave
MNS	mission need statement
MOA	memorandum of agreement
MOCVD	metallo-organic chemical vapor deposition
ModSAF	modular semiautomated forces
MOMBE	metallo-organic molecular beam epitaxy
MOP	measure of performance
MOS	metal oxide semiconductor
MOU	memorandum of understanding
MOUT	military operations in urban terrain
MP&S	materials, processes, and structures
MPM	microwave power module
MRE	meals, ready to eat
MRF	Materials Research Facility
MRL	multiple rocket launcher
MRMAAV	multirole mission adaptable air vehicle
MRMC	Medical Research & Materiel Command
MS	mass spectrometry; milestone
MS&T	manufacturing science and technology
MSBL	Maneuver Support Battle Laboratory
MSC	major subordinate command
MSCM	multispectral countermeasures
MSE	mobile subscriber equipment
MSEG&C	multispectral environmental generator and chamber
MSIP	multispectral imagery [system]; multi-stage improvement program
MSRC	major shared resource center
MSTAR	MLRS smart tactical rocket
MTBF	mean time between failures
MTBR	mean time between replacements
MTI	moving target indicator
MTO	Manufacturing Technology Objective
MTTC	MANTECH Technical Council
MTTR	mean time to repair
MULE	modular unammned logistics express
MURI	Multidisciplinary University Research Initiative

N

nm	nanometer
NA	nerve agent
NAC	National Automotive Center
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization

NBC	nuclear, biological, and chemical
NCA	National Command Authority
NCO	noncommissioned officer
NDE	nondestructive evaluation
NDI	nondevelopmental item
NEDT	noise-equivalent delta temperature
NEOF	no evidence of failure
NGLCSEC	next-generation life-cycle software engineering center
NIR	near infrared
N–ISDN	narrowband integrated services digital network
NIST	National Institute of Standards and Technology
NLO	nonlinear optical
NMD	national missile defense
NMRI	Naval Medical Research Institute
NMRL	Nuclear Magnetic Resonance Laboratory
NMS	National Military Strategy
NOAA	National Oceanic and Atmospheric Administration
NOE	nap of the earth
NRDEC	Natick Research, Development, and Engineering Center
NRO	National Reconnaissance Office
NRT	near real time
NRTC	National Rotorcraft Technology Center
NSA	National Security Agency
NSC	National Security Council
NSF	National Science Foundation
NSTD	nonsystem training device
NTAPS	near-term active protection system
NTC	National Training Center

O

O&M	operation and maintenance
O&S	operation and support
OASA(RDA)	Office of the Assistant Secretary of the Army (Research, Development and Acquisition)
OBIDS	on-board integrated diagnostic systems
OCONUS	outside the continental United States
OCR	operational capability requirement
OCSW	objective crew-served weapon
ODCSOPS	Office of the Deputy Chief of Staff for Operations and Plans
ODS	ozone depleting substance
OICW	objective individual combat weapon
OLTC	open-loop tracking complex
OMB	Office of Management and Budget
OOTW	operations other than war
OPFOR	opposing force
OPO	optical parametric oscillator
OPTEC	Operational Test and Evaluation Command
OPW	objective personal weapon
ORD	operational requirements document
ORTA	Office of Research and Technology Applications
OS	operating system
OSCR	operating and support cost reduction
OSD	Office of the Secretary of Defense
OSW	objective sniper weapon
OT&E	operational test and evaluation
OTM	on the move

P

pH	a value to express acidity and alkalinity
P_h	probability of hit
P_i	probability of incapacitation
P_{kill}	probability of kill
ppm	parts per million
P^3I	preplanned product improvement
PAC^3	Patriot advanced capability
PATS	protection assessment test system
PBX	private branch exchange
PC	personal computer
PCR	polymerase chain reaction
PCS	personal communication system
PDF	probability density function
PDRR	program definition and risk reduction
PEM	programmable electronic module; proton exchange membrane
PEO	Program Executive Office
petaflops	10^{15} floating point operations per second
PGMM	precision-guided mortar munition
PIP	product improvement program; product improvement proposal
P.L.	Public Law
PLA	patent license agreement
PLD	pulsed laser deposition
PLIF	planar laser-induced fluorescence
PM	program manager
POM	program objective memorandum
POS/NAV	position/navigation
PPBES	planning, programming, budgeting, and execution system
PPSB	power projection and sustaining base
PP&T	personnel performance and training
PQA	petroleum quality analysis
PSA	pressure swing adsorption
PVC	polyvinyl chloride

Q

QRMP	quick-response multicolor printer
QW	quantum well
QWIP	quantum well infrared photodiode

R

R&D	research and development
RACE	rotorcraft air combat enhancement
RAM	random access memory
RAMS	remote activation munitions system
RAP	radio access point
RASTR	real aperture stationary target radar
RC	Reserve component

RCS	radar cross section
RD&E	research, development, and engineering
RDA	research, development, and acquisition
RDEC	research, development, and engineering center
RDT&E	research, development, test, and engineering
REAP	Research and Engineering Apprenticeship Program
RF	radio frequency
RFCM	radio frequency countermeasure
RFP C^2	rapid force projection command and control
RFPI	rapid force projection initiative
RISTA	reconnaissance infrared surveillance and target acquisition
RITA	Rotorcraft Industry Technology Association
RML	*Revolution in Military Logistics*
RPA	rotorcraft pilot's aircraft
RPV	remotely piloted vehicle
RSOP	reconnaissance, selection, and occupation of position
RSTA	reconnaissance, surveillance, and target acquisition
R-T	real time
RTM	resin transfer molding; requirements translation model
RTSP	reactive topical skin protectant
RTU	remote terminal unit
RTV	rapid terrain visualization
RWST	rotary wing structures technology
RWSTD	Rotary Wing Structures Technology Demonstration
RWV	rotary wing vehicle

S

S&A	safe and arm
S&PS	survivability and protective structure
S&T	science and technology
S&TF	systems and technology forum
S/SU/AC	system/system upgrade/advanced concept
Si	silicon
SiC	silicon carbide
SADARM	sense and destroy armor
SAF	semiautomated force
SAFOR	semiautomated forces
SAL	semiactive laser
SAM	surface-to-air missile
SAR	synthetic aperture radar
SARAP	survivable, affordable, repairable airframe program
SARD	Assistant Secretary of the Army (Research, Development, and Acquisition)
SASO	stability and support operations
SATCOM	satellite communications
SBIR	Small Business Innovation Research
SBIRS	space-based infrared system
SC	Simulation Center
SCAMP	single-channel antijam man-portable
SCAPP	standardized camouflage paint pattern
SCAPS	site characterization and analysis penetrometer system
SCDMS	structural crash dynamics modeling and simulation
SDF	synthetic discriminant function
SEAD	suppression of enemy air defense
SEAP	Science and Engineering Apprentice Program
SEB	staphylococcal enterotoxin
SEM	science, engineering, and mathematics
SEM–E	standard electronic module—format E
SEP	soldier enhancement program
SER	system evolution record
SERDP	Strategic Environmental Research and Development Program
SFREP	Summer Faculty Research and Engineering Program
SGI	Silicon Graphics Incorporated
SHF	super high frequency
SHTU	simplified handheld terminal unit
SICP	single integrated command post
SIGINT	signals intelligence
SIL	system integration laboratory
SIMITAR	simulation in training for advanced readiness
SIMNET	simulation network
SINCGARS	single-channel ground and airborne radio system
SIP	system improvement program
SLAIR	survivability/lethality advanced integration in rotorcraft
SLBD	Sea Lite Beam Director
SLM	spatial light modulator
SMART	sensor mounted as roving thread
SMDBL	Space and Missile Defense Battle Laboratory
SMDC	Space and Missile Defense Command
SOA	special operations aircraft
SOCOM	Special Operations Command
SOF	Special Operations Forces
SOL	structured query language
SPG	Scientific Planning Group
SQL	structured query language
SRO	Strategic Research Objective
SSES	suite of survivability enhancement systems
STAR	Strategic Technologies for the Army of the 21st Century
STARLITE	surveillance targeting and reconnaissance satellite
STARLOS	SAR Target Recognition and Location System
STARS	software technology for adaptable, reliable systems
STAS	subsystems technology for affordability and supportability; short-term analysis service

STI	stationary target indicator
STIRR	subsystems technology for infrared reductions
STO	Science and Technology Objective
STOW	synthetic theater of war
STRATA	simulator training research advanced testbed for aviation
STRICOM	Simulation, Training, and Instrumentation Command
STRV–2	space technology research vehicle
STTR	Small Business Technology Transfer
SUO	small unit operations
SUSOPS	sustained operations

T

teraflops	10^{12} floating point operations per second
ti	titanium
T&D	transport and diffusion
T&E	test and evaluation
TACOM	Tank–Automotive and Armaments Command
TACSIM	tactical simulations
TAD	theater area defense
TADSS	training aids, devices, simulators, and simulations
TARA	Technology Area Review and Assessment
TARDEC	Tank–Automotive Research, Development, and Engineering Center
TBM	theater ballistic missile
TCG	Technical Coordiation Group
TCP/IP	transmission control protocol/Internet protocol
TD	Technology Demonstration
TDA	technology development approach
TEC	Topographic Engineering Center
TECOM	Test and Evaluation Command
TEED	tactical end-to-end encryption device
TEG	tactical exploitation group
TEMO	training, exercise, and military operations
TENCAP	tactical exploitation of national capabilities
TERM	tank extended range munitions
TES	tactical exploitation system
TESAR	tactical synthetic array radar
THAAD	theater high altitude area defense
TI	tactical internet
TIBS	tactical information broadcasting system
TIER	unmanned aerial vehicle TIER II
TIS	tactical input segment
TMD	theater missile defense
TOC	Tactical Operations Center
TOW	tube-launched, optically tracked, and wire command-link guided [missile]
T.P.	TRADOC pamphlet
TP	thermoplastic
TPSO	theater precision strike operations
TPV	thermophotovoltaic
TRAC	TRADOC Analysis Center
TRADOC	Training and Doctrine Command
TRE	tactical receiver equipment
TSA	temperture swing adsorption
TTP	tactics, techniques, and procedures
TUAV	tactical unmanned aerial vehicle
TWS	thermal weapon sight
TWT	traveling wave tube

U

UAV	unmanned aerial vehicle
UGV	unmanned ground vehicle
UHF	ultra high frequency
ULCANS–GP	ultra-lightweight camouflage net system—general purpose
UMD	University of Massachusetts at Dartmouth
UNITE	Uninitiaties Introduction to Engineering
UPAS	unit performance assessment system
UPC	unit production code
URI	university research initiative
U.S.	United States
USAAIC	United States Army Artificial Intelligence Center
USAF	United States Air Force
USAIS	United States Army Infantry School
USAMRICD	United States Army Medical Research Institute of Chemical Defense
USAMRIID	United States Army Medical Research Institute for Infectious Diseases
USARIEM	United States Army Research Institute of Environmental Medicine
USASMDC	United States Army Space and Missile Defense Command
U.S.C.	*United States Code* (publication)
USDA	United States Department of Agriculture
USFK	U.S. Forces Korea
USMA	United States Military Academy
USMC	United States Marine Corps
USN	United States Navy
UV	ultraviolet
UWB	ultra wideband
UWV	unmanned wheeled vehicle
UXO	unexploded ordnance

V

V&V	verification and validation
VASTC	Virtual Advanced Software Technology Consortium
VCSA	Vice Chief of Staff of the Army
VCSEL	vertical/cavity surface emitting laser
VE	virtual environment
VEES	vehicle engine exhaust smoke
VHDL	VHSIC hardware descriptive language
VHF	very high frequency
VHSIC	very high speed integrated circuit
VMF	variable message format
VMMD	vehicular-mounted mine detector
VMS	vehicle management system
VOC	volatile organic compound
VR	virtual reality

VSD	virtual simulation directorate
VSIL	vehicle systems integration laboratory
VTOL	vertical take-off and landing
VV&A	verification, validation, and accreditation
VX	[chemical agent] VX

W

W	watt
WAM	wide area munition
WAN	wide area network
WARSIM	warfighter simulations
Web	World Wide Web
WES	Waterways Experiment Station
Wh	watt hour
WIN	warfighter information network
WIT	wireless interworking testbed
WMD	weapon of mass destruction
WP&S	warrior protection and sustainment
WRAIR	Walter Reed Army Institute of Research
WRAP	Warfighting Rapid Acquisition Program

Y

YPG	Yuma Proving Ground